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Gamification of collaborative learning scenarios: an ontological engineering approach to deal with the motivation problem caused by computer-supported collaborative learning scripts

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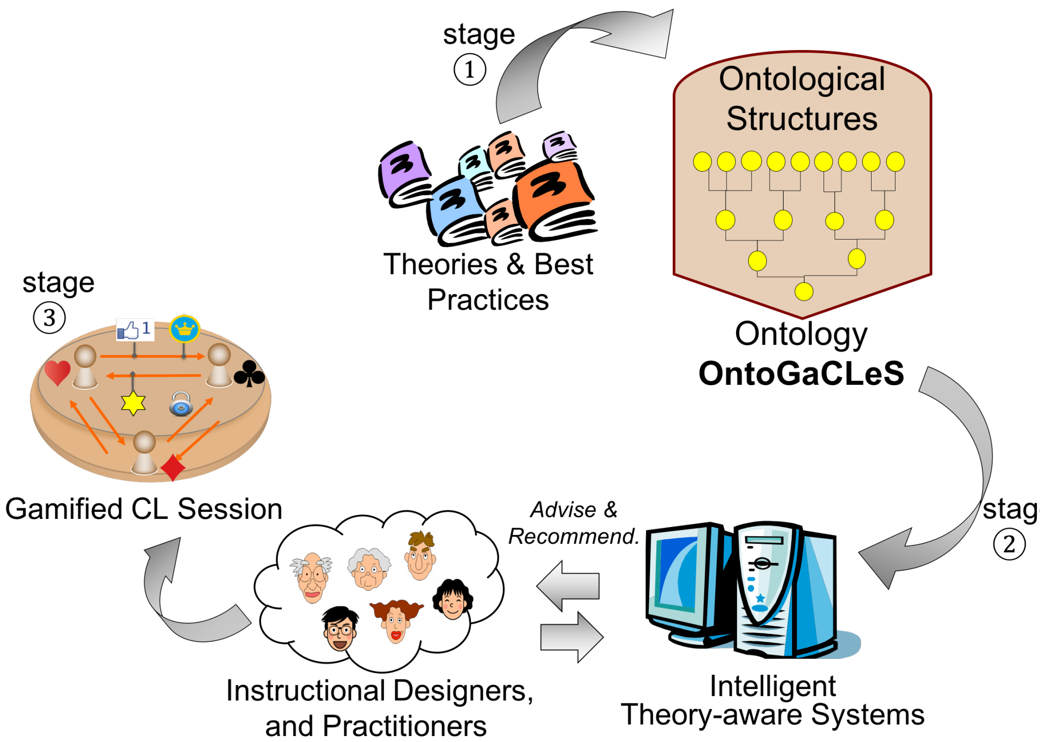
to orchestrate and structure the collaboration among students.

1.2 Research Questions and Research Objectives

The overarching research question (**RQ**) answered in this PhD thesis dissertation is: "*How can gamification and ontologies be used to deal with the motivation problem caused by the scripted collaboration in CL activities where CSCL scripts are used as a method to orchestrate and structure the collaboration among students?*"

To answer this research question, the author of this thesis proposes the ontological engineering approach to gamify CL scenarios shown in Figure 1. This approach consists into three major stages described as follows:

Figure 1 – Ontological engineering approach to gamify CL scenarios



Source: Elaborated by the author.

1. The first stage is the formalization of the necessary knowledge about how to gamify CL scenarios for dealing with the motivation problem caused by the scripted collaboration into an ontology named **OntoGaCLeS** – ***Onto**logy to **Ga**mify **C**ollaborative **Le**arning **S**cenarios*. This ontology has been developed using ontology engineering in which, by extracting concepts from the theories and practices related to gamification, the author of this thesis defines a set of ontological structures that enables the systematic formalization and representation of necessary knowledge to gamify CL scenarios.

2. The second stage is the development of computer-based mechanisms and procedures whereby intelligent theory-aware systems will provide support in the gamification of CL scenarios to deal with the motivation problem caused by the scripting collaboration. Such support is given by the knowledge formalized in the ontology OntoGaCLeS during the first stage, and the purpose of the computer-based mechanisms is to use this knowledge to facilitate the tasks of instructional designer and practitioners, especially novice users, in the gamification of CL scenarios. This knowledge provides theoretical justification for the personalization of gamification and, thus, to obtain tailored gamified CL sessions adapted for each situation. Such sessions are known as ontology-based CL sessions, and they are CL scenarios that have been gamified and instantiated at the most concrete level by detailing the participants and content-domain to be directly run in a learning environment.
3. The third stage is the validation of the ontological engineering approach to gamify CL scenarios as a method to deal with the motivation problem caused by the scripted collaboration. This validation is carried out in ontology-based gamified CL sessions obtained by the approach, and it consists in measuring the effectiveness and efficiency of these sessions for dealing with the motivation problem caused by the scripted collaboration. The effectiveness and efficiency were measured by comparing the effects on students' motivation and learning outcomes caused by ontology-based CL sessions, non-gamified CL sessions and CL sessions gamified without using the support given by the ontology OntoGaCLeS.

Regarding to the formalization of knowledge about how to gamify CL scenarios for dealing with the motivation problem caused by the scripted collaboration (Stage 1), the research questions answered by this dissertation are:

RQ1: Which concepts from the theories and practices related to gamification should be taking into account to deal with the motivation problem caused by the scripted collaboration? and How should these concepts be applied in the gamification of CL scenarios?

RQ2: How can the concepts extracted from the theories and best practices related to gamification, and identified as relevant to deal with the motivation problem caused by the scripted collaboration, be represented as ontological structures?

Regarding to the development of computer-based mechanisms and procedures whereby intelligent theory-aware systems will provide support in the gamified CL scenarios using the knowledge described in the ontology OntoGaCLeS (Stage 2), the research questions answered by this dissertation are:

RQ3: What computer-based mechanisms and procedure are necessary in intelligent-theory aware systems to give a helpful support in the gamification of CL scenarios? and How can

CHAPTER

2

GENERAL BACKGROUND AND FUNDAMENTAL CONCEPTS

This chapter presents the general background and fundamental concepts related to the domain problem that is addressed in this thesis. At the first section (section 2.1), an overview of the CSCL field and scripted collaboration is presented to provide a comprehensive and clear understanding about the research context. The section 2.2 elaborates an overview of gamification, and the best practices and theories related to this technology. Finally, the section 2.3 presents the fundamentals of ontologies and ontology engineering.

2.1 CSCL and Scripted Collaboration

Although CL has a long history in education, it is not until the early 1990s that the research field dedicated to study how to provide support for the CL through the use of Internet and computational technology had gained attention and strength (STAHL; KOSCHMANN; SUTHERS, 2006). Such research field known as Computer-Supported Collaborative Learning (CSCL) is a multidisciplinary field that combines studies from the cognitive psychology education and from the computer science to effectively enhance the CL process through the use of computational technology (HOPPE; OGATA; SOLLER, 2007).

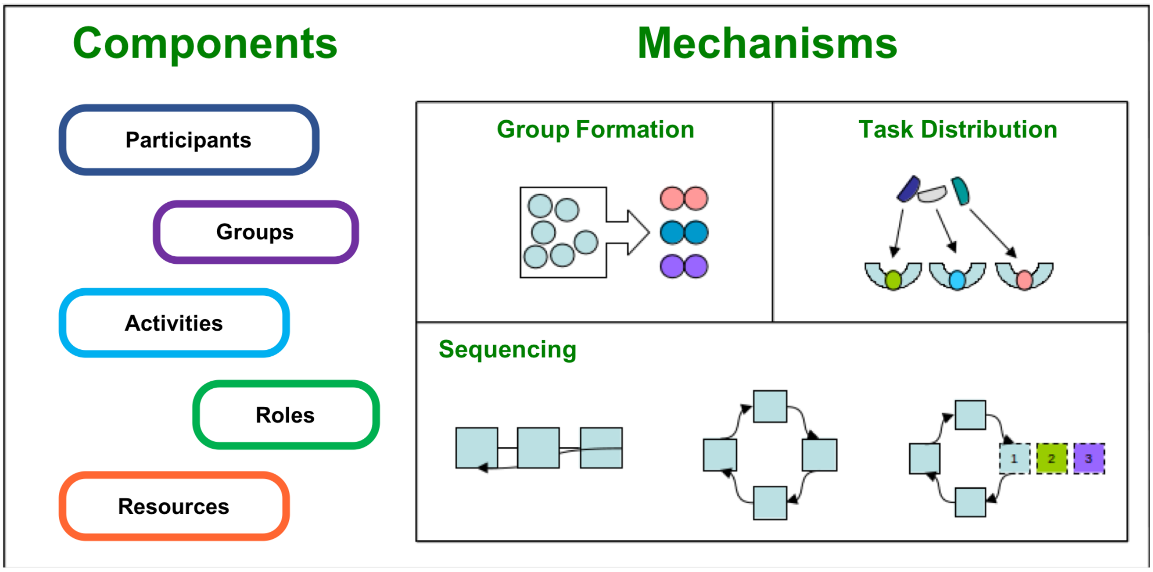
The general aim of CSCL field is to develop technologies to support or create situations in which two or more students learn together through the interaction among them (DILLENBOURG, 1999). In these situations, the learning outcomes is consequence of students' interactions and how these interactions affect the individual learning for each one of the students. In consequence, to enable a well-though-out design of CL, the CSCL scripts have been proposed by the CSCL community as the technology to facilitate the social and cognitive processes of learning by describing the way in which the learners will interact with each other in a CL scenario (HARRER; KOBBE; MALZAHN, 2007).

2.1.1 CSCL Scripts

CSCL scripts are the technology that describes how to structure and orchestrate the CL process to attain a set of pedagogical objectives defined by an instructional design (DILLENBOURG; JERMANN, 2007). Such description is provided in the CSCL scripts through prescribed instructions that indicates how to facilitate the social and cognitive processes in group activities (DILLENBOURG, 2002). These prescribed instructions are defined by instructors, like teachers or instructional designers, as a way to attain a set of learning goals, and they indicate the way in which students should collaborate, they constrain the interactions among the participants, they specify the roles for the participants, they indicate the distribution of task, tools, and resources used in the CL process.

In order to narrow the number of elements used to describe the CSCL scripts, and provide a common and sharable description of CSCL scripts, Kobbe *et al.* (2007) propose a framework that is currently wide accepted by the community as the common specification to describe the CSCL scripts using natural language. This framework formalizes the CSCL scripts as a set of components and mechanisms illustrate in Figure 2.

Figure 2 – Components and mechanisms of CSCL scripts

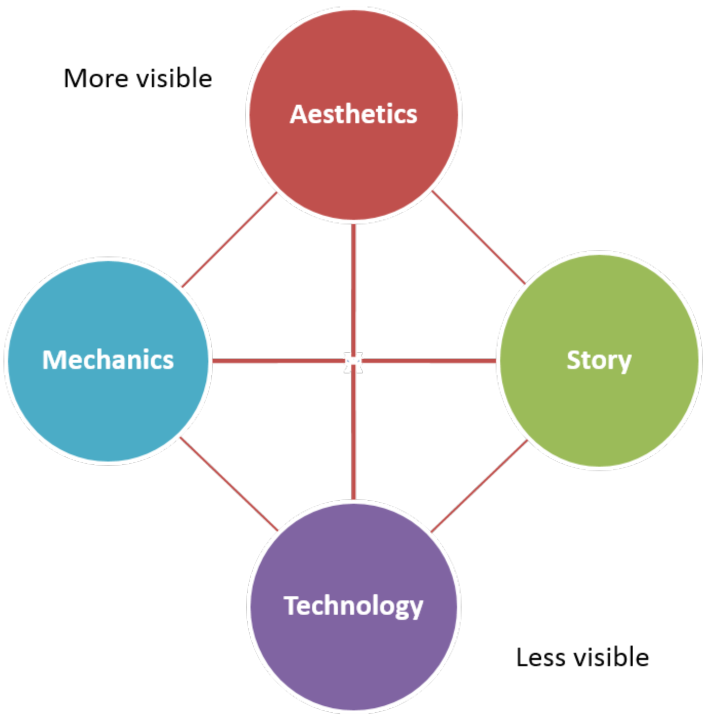


Source: Adapted from Fischer (2007).

The structural *components* of CSCL scripts are the participants, groups, activities, roles and resources. The component of *participants* is used to describe the participants, such as learners, monitors, and teachers. Although this description can be abstract or concrete and simple or complex, it is often presented in a simple manner with rules that indicate conditions to participate in the CL process. The component of *activities* describes what will be performed by the participants in the CL process to attain the learning goals defined by the instructional designers. The component of *roles* describes the privileges, obligations and expectations of participants in the CL process. The component of *groups* of participants defines through hierarchical structures

Frequently, the problems are viewed as something negative, but people really do get pleasure from solving them. As humans, our complex brains enjoy solve problems, and this is our primary advantage as a species. Frequently, people who enjoy solving problems are going to solve more problems, and get better at solving problems. Games are not simply problem-solving activities, one who plays games must have sufficient motivation to solve problem, and it means having playful attitude.

Figure 3 – Elements and components of games



Source: Schell (2008).

There are many ways to classify the elements that are part of a game. According to Schell (2008), these elements as shown in Figure 3 are classified in the following four basic elements:

Mechanics: These are rules and procedures that are used to describe the goals of games, how game players can try to achieve them, and what happen when they try.

Story: This is the sequence of events (script) that unfold in your game. It may be pre-scripted, linear, or complex with branching and emergent. In general, the mechanics that will be used must strengthen the story, and the mechanics will also help reinforce the ideas of story.

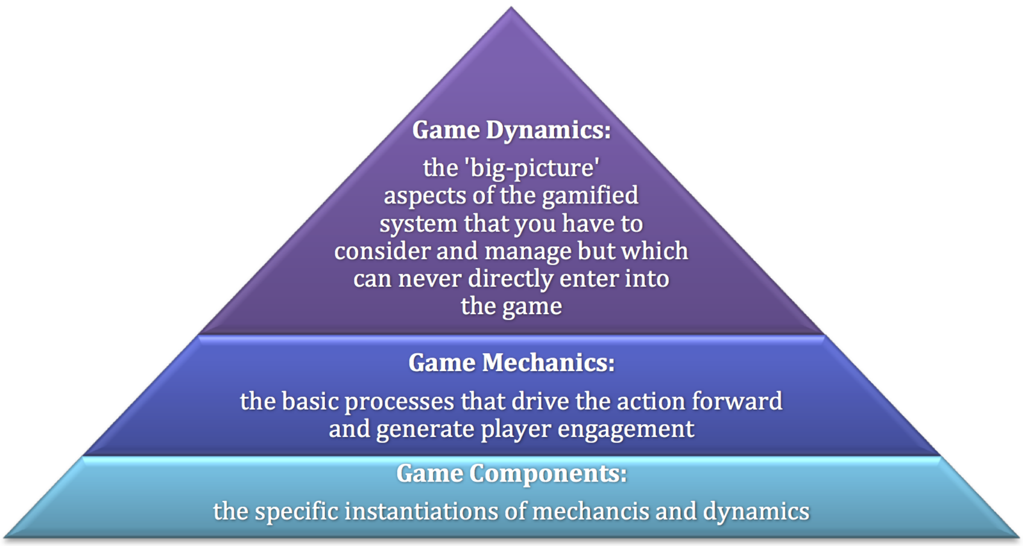
Aesthetics: There are how your game looks, sounds, smells, tastes, and *feels*. They are an important aspect of game design that have most direct relationship to a player's experience during the game (gameplay experience).

Technology: This is the materials and interactions that make your game possible. It is the medium in which the aesthetics happen, in which the mechanics will occur, and through which the story will be told.

Although the elements listed above define the components of a game, the essence of a game is rooted in the interactive nature in which the users act as players (SCHELL, 2008). The player puts his mind inside the game world, but the game world really only exists in the mind of the player. This magical situation is made possible by the game interface, which is where player and game come together. Thus, the goal of a good game interface is not to look nice or to be fluid, although those are nice qualities, the goal of a game interface is to make players feel in control of their experience because the purpose of a game is by itself to create an experience in the user mind.

According to Werbach and Hunter (2012), the game elements are described as smaller pieces used to build blocks that, in an integrate form, constitutes gameplay experience. Thus, these game elements are separate in three categories: dynamics, mechanics and components, described in Figure 4.

Figure 4 – Hierarchical classification of game elements



Source: Werbach and Hunter (2012).

Based on the hierarchy of game elements showed in Figure 4, the game elements are classified as:

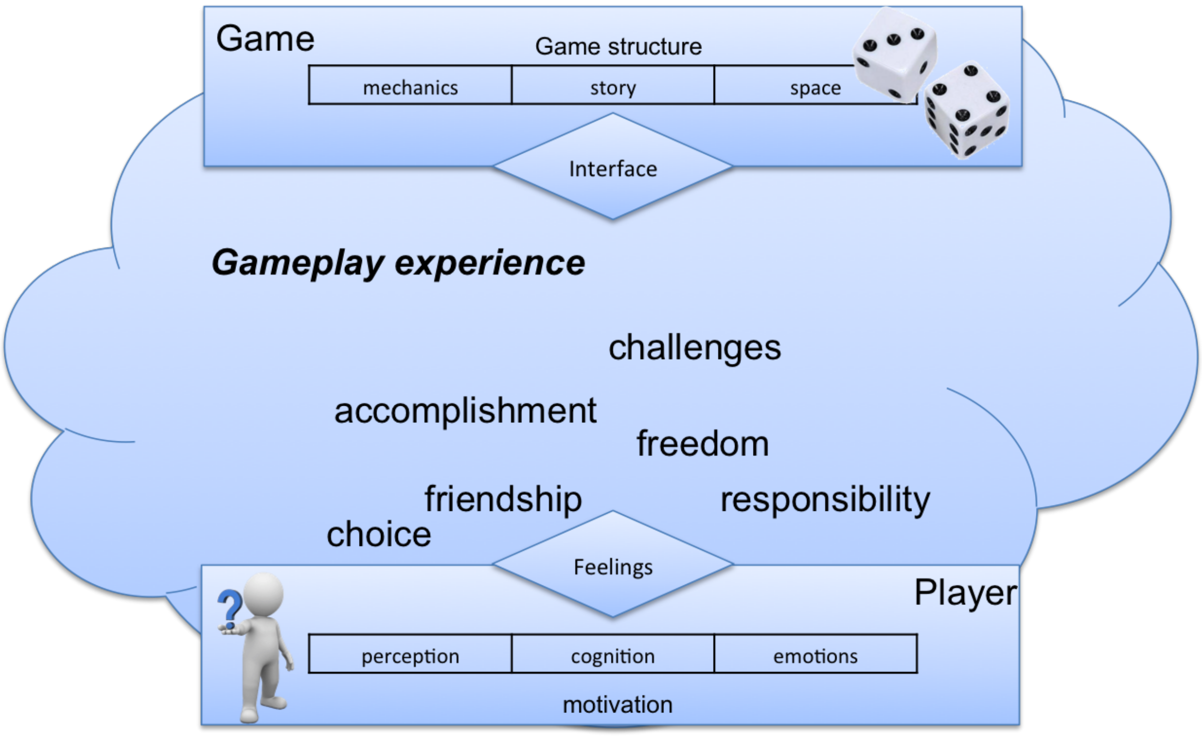
Game Dynamics when the game element are the big-picture aspects of the game-like system that can be to consider and manage but which you can never directly enter into the game. e.g. constraints, emotions, narrative, progression, relationships, and personalization.

Game Mechanics when the game element is part of the basic processes that drive the action forward and generate player engagement. e.g. challenges, chance, competition, cooperation, feedback, resource acquisition, rewards, transactions, turns, win-states, and profiles.

Game Component when the game element is the more-specific forms that mechanics or dynamics can take. e.g. achievements, badges, collections, leaderboards, levels, notifications, points, progress bars, quests/missions, status, teams, and virtual goods.

The *gameplay experience*, or simply called *gameplay*, is the player's interpretation of manner in which a player or players interacted in a game world (SALEN; ZIMMERMAN, 2004; LINDLEY, 2004; MÄYRÄ; ERMI, 2005). Figure 5 shows the relation among the fundamental components which are part in the formation of gameplay experience. The model showed here is not intended to constitute a comprehensive analysis of all possible elements between a game and a player, the game is represented as a structure (of mechanics, story, and space) that engenders the gameplay experience in the mind of the player through a game interface. Thus, the gameplay experience happens by linking perception, cognition, and emotions when a person does actions that are motivated by the game (motivation).

Figure 5 – Fundamental components in the gameplay experience



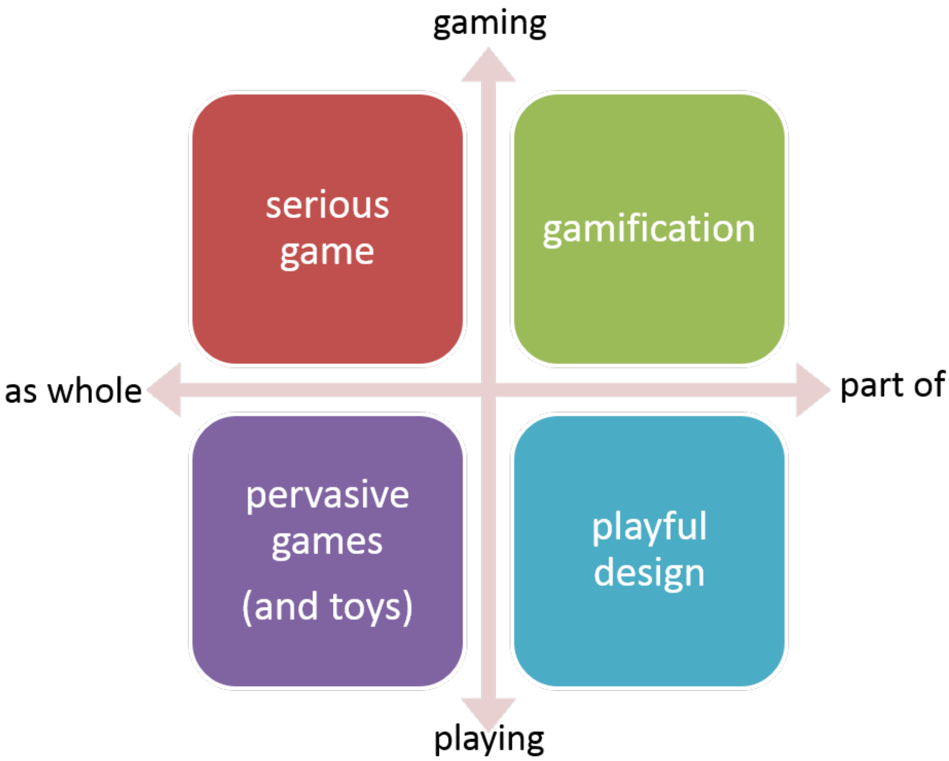
Source: Adapted from Mäyrä and Ermi (2005).

There are certain feelings, feelings of choice, feelings of freedom, feelings of responsibility, feelings of accomplishment, feelings of friendship, and many others, which only gameplay experience seems to offer (SCHELL, 2008). The gameplay experience is not identical in people, each person has completely different and unique experience playing a game, but the experience is imaginary. Thus, the game designers must have careful selection the proper game elements, such as game mechanics, game interfaces, among others, that are used to create certain kinds of experiences when a player interacts with them. This task is known as *game design*, and it is basic when some situation, scenario or application is being gamified.

2.2.2 What Is Gamification? and What Is It Not?

While no standard conceptualization of gamification exists, most studies agree that gamification generally refers to the use of game-based elements, such as game mechanics, aesthetics, and game thinking in non-game contexts aimed at engaging people, motivating action, enhancing learning, and solving problems (BORGES *et al.*, 2014; KAPP, 2012). However, it is important a deeper and scientific conceptualization to identify theoretical foundations, purposes, and knowledge about how to apply gamification in practice. In this sense, based on the work of academics and industry practitioners, Deterding *et al.* (2011) establish the conceptualization of gamification as the use of game design elements in non-game contexts, and Werbach (2014) defines gamification as the process of making activities more game-like. In other words, it covers coordinated practices that objectively manifest the intent to produce more of the kinds of experiences that typify games.

Figure 6 – Situating gamification in the scope of game design technology



Source: Adapted from Deterding *et al.* (2011).

Figure 6 shows where gamification and others game design technology are situated based on the degree of design (as whole or parts) and purpose (for playing or gaming). As we can see in the figure, gamification and serious game are similar in terms of purpose, but they differ in the degree of design, both are made for non-entertainment purposes, serious game describes the design of application as a whole game, while gamification describes the design of application as part of whole. Gamification and playful design have the same degree of design, both implements parts of application as game, while the purpose of playful design is entertainment as a desirable user experience or mode of interaction, and gamification is made for non-entertainment.

According to Deterding *et al.* (2011), gamification is related to gaming, not playing or playfulness, where playing denotes a free-form of expression, improvisational, even tumultuous recombination of behaviors and meanings. Gaming consists in the capture of playing that is structured by rules-base systems. Gamification does not describe the design of full-fledged games, gamified applications merely incorporate elements of games (also called game atoms (BRATHWAITE; SCHREIBER, 2009)). However, these elements do not refer game-based technologies or other game related practices (e.g. as authoring tools, graphic engines), gamification is only reserved for the use of game design. The use of game design elements in gamification is for purposes other than the normal expected use as part of an entertainment game (for non-entertainment purpose).

2.2.3 Outcomes of Gamification

When gamification is properly applied, a wide range of desired outcomes can be achieved, such as enjoyment, engagement, fun, satisfaction, motivation, loyalty, participation, efficiency, and behavior change (HAMARI; KOIVISTO; SARSA, 2014). In this sense, the outcomes of gamification as shown in Figure 7 can be seen as: (1) the psychological outcomes (i.e. motivation, engagement, enjoyment, and fun) that are results of implemented motivational affordance (i.e. badges, points, leaderboards, and feedbacks); and (2) the behavioral outcomes (i.e. response pattern, duration of interactions, participation, and learning) that are result of psychological outcomes.

Figure 7 – Expected outcomes of gamification

Source: Adapted from Hamari, Koivisto and Sarsa (2014).

In educational contexts, most studies, as shown in Chart 3, propose the engagement of learners as psychological outcomes, and the improving of learning as behavioral outcomes (BORGES *et al.*, 2014). For example, Li, Grossman and Fitzmaurice (2012) investigated how story/theme, clear goals, feedbacks, challenge and rewards (motivational affordance) could be used to increase the engagement and enjoyment (psychological outcomes) of students, and the results showed an increase in the speed of completion of tasks (behavioral outcomes).

Chart 3 – Outcomes of gamification in educational contexts

Source	**Motivational Affordances**	**Psychological Outcomes**	**Behavioral Outcomes**
(CHEONG; CHEONG; FILIPPOU, 2013)	points, feedback, leaderboards, time constraints (challenge)	enjoyment, engagement	impact on learning (usefulness)
(DENNY, 2013)	badges	enjoyment, attitude towards badges	level and quality of participation
(DOMÍNGUEZ *et al.*, 2013)	leaderboards, badges	attitude towards gamification	learning outcomes
(DONG *et al.*, 2012)	clear goals, challenge, feedback, levels, story/theme	engagement, fun	effectiveness of learning
(Fitz-Walter; TJONDRONEGORO; WYETH, 2011)	achievements, clear goals	perceived added value of gamification, fun	exploration of the campus while interacting with the application
(HAKULINEN; AUVINEN; KORHONEN, 2013)	badges		impact on time management, carefulness and achieving learning goals
(HALAN *et al.*, 2010)	leaderboards, narrative (story/theme), deadline (challenge)	difference in users' approach to virtual patient interaction	Number and duration of interactions with virtual patients, likelihood of voluntary participation to a virtual patient interaction
(LI; GROSSMAN; FITZMAURICE, 2012)	story/theme, clear goals, feedback, challenge, rewards	engagement, enjoyment	task performance
(SMITH; BAKER, 2011)	story/theme, rewards		increasing knowledge about the library, its services and resources, teaching library skills

Source: Adapted from Hamari, Koivisto and Sarsa (2014).

2.2.4 Theories and Models of Motivation

As defined by Mitchell and Daniels (2003), motivation is an internal set of processes what is referred as hypothetical construct associated with three general psychological processes (arousal, direction, and intensity). The arousal is the first component caused by the need or desire to some object or state that is at least partially unfulfilled or below expectation. This discrepancy initiates the action to satisfy the need, to obtain the desired object or to achieve the unfulfilled state. Moreover, this discrepancy is personal, and differs in each individual, different people have different needs and different things that they think are important. Thus, the second is a directional component defined by personal goals and goal discrepancies that are seen as major goads to attention and action. The third component is the intensity dimension defined by the goal difficulty and importance of arousal because some needs are more important than others, and some goals are more difficult to attain than others.

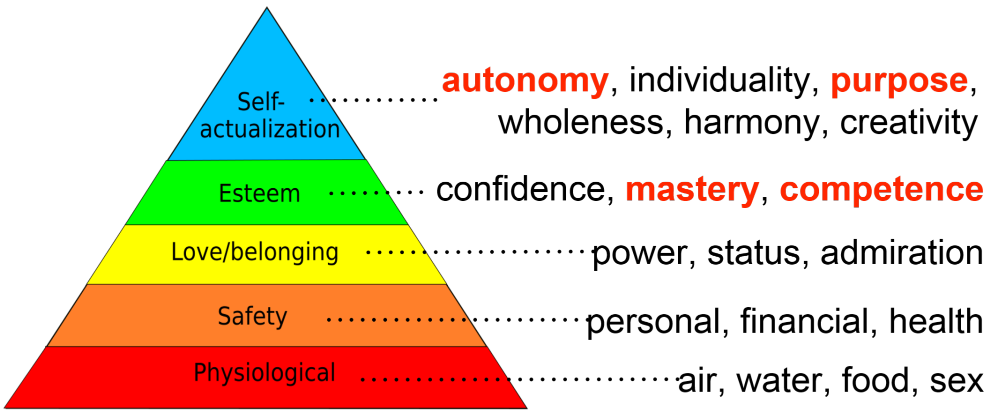
Having knowledge about how to motivate people, it is possible to build and formalize the proper understanding of what pushes people to interact in a gamified application, what make it fun, and why it is enjoyable. In this direction, there are different theories and models of motivation related to gamification, that are briefly summarized as follows.

2.2.4.1 Need-based Theories

There are many theories that revolve around the fulfillment of humans' needs, defined as the arousal component of motivation. These theories describe what make certain outcomes appear attractive, and they constitute the basic foundations of motivation. With relation to gamification, there are three main need theories that are detailed in the paragraphs below.

Maslow's hierarchy of needs theory states that a person has a pyramid hierarchy of needs that a person must satisfy from bottom to top (MASLOW, 1954; GOBLE, 1970). As shown in Figure 8, the Maslow's need pyramid classifies the needs from basic to complex in five categories: physiological, safety, love/belonging, esteem, and self-actualization.

Figure 8 – Maslow's pyramid of need

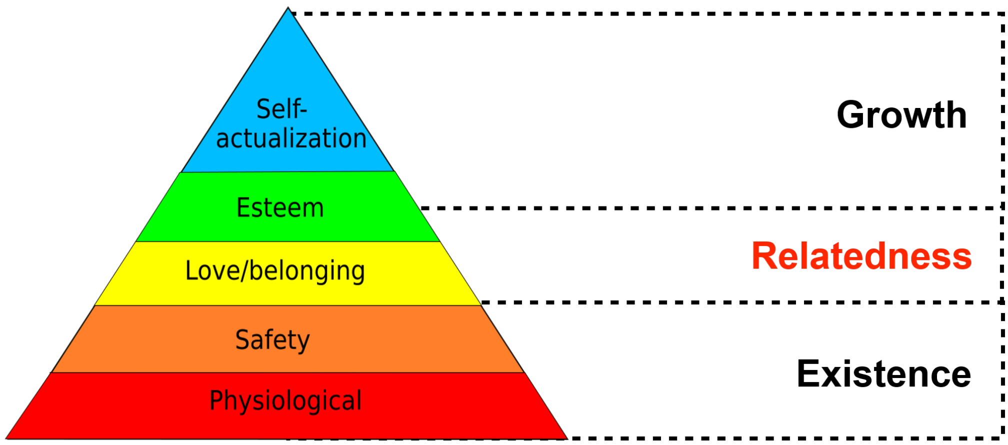


Source: Adapted from Maslow (1954).

According to Huitt (2004), only unsatisfied human needs influence behavior, if there is a deficit in a lower level, all behaviors of an individual will be oriented to satisfy this deficit. In the Maslow's need pyramid, needs are arranged in order of importance to human life, as said before from the basic to the complex.

Alderfer's ERG Theory, as shown Figure 9, condenses Maslow's pyramid hierarchy of needs in three categories: Existence (material and physiological), Relatedness (social and external esteem) and Growth (internal esteem and self-actualization) (ALDERFER, 1969; ALDERFER, 1972).

Figure 9 – Relation between Maslow's hierarchy of needs theory and Aldefer's ERG theory



Source: Elaborated by the author.

Different to Maslow's hierarchy of needs theory, a person can regress to a basic level from a complex level if a relatively more significant need (of complex level) is not satisfied (ALDERFER, 1972). Thus, a person may satisfy a need at hand, whether or not a previous need has been satisfied. Finally, the theory states that the order of needs to differ for different people.

Self-Determination Theory (SDT) is one of the most well-known theory related to motivation. Through the understanding of needs and motivation, this theory explains the human beings' innate psychological needs for personal development and well-being, and the impact of the environment on individual's motivation (DECI; RYAN, 2010; RYAN; DECI, 2000). SDT defines three innate needs (competence, relatedness, and autonomy) that cause individual motivation, and when these needs are fulfilled they invoke great personal growth (ARAZY; GELLATLY, 2012).

According to SDT theory, the three needs are not learned, and they are seen as universal necessities in humanity across time, gender and culture. They are summarized as follows:

- *Autonomy* is the need to have independence and to be able make own choices (DECI; RYAN, 2010). Deci and Vansteenkiste (2004) states that autonomy does not mean to be independent of other persons. In a game, an example is to give a player freedom to make his own choices among various paths to choose.

- *Relatedness* is the need to be connected with others, iterate with them, and experience caring for them (BAUMEISTER; LEARY, 1995). In a game, there are many elements that allow a player socializer with other players.

- *Competence* is the need to control the outcomes and experience a sense of ability (mastery) (WHITE, 1959). In a game, when a player sees a leaderboard or progress state, he or she increases their proficiency and skills.

In the SDT, there are two categories of motivation: intrinsic motivation, and extrinsic motivation (DECI; VANSTEENKISTE, 2004). Extrinsic motivation occurs when an external stimulus evokes a target behavior. Some of these stimulus can be rewards, threats, punishment, pressure, external regulations, and rules. The intrinsic motivation comes from individuals, and pushes them to act for the sake of the activity itself (DECI; RYAN, 2010). The intrinsic motivation occurs when the behavior is itself rewarding or engaging for the individual. The intrinsic motivators act on the human predisposition to strive for novelty and challenges, to extend and exercise one's capacities, to explore and to learn (RYAN; DECI, 2000). These intrinsic motivators include altruism, competition, cooperation, sense of belonging, love or aggression (MUNTEAN, 2011).

On the one hand, the use of extrinsic motivators is a highly reliable technique for behavioral change, but the behavior disappears instantly when these external motivators are halted (HAGGER; CHATZISARANTIS, 2007). On the other hand, intrinsic motivation is intense, and lasting engagement in the behavior, but it cannot be predicted every each person as it is internalized (DECI; RYAN, 2010). Internalization of motivation refers to the active attempt to transform an extrinsic motive into personally endorsed values. It means the assimilation of behavioral regulations that were originally external.

2.2.4.2 Skinner's reinforcement theory

The reinforcement theory or operant conditioning theory proposed by Skinner (1976) states that reinforced behaviors will tend to be repeated, while punished behavior tend to be decrease and will eventually end. Thus, the operant conditioning is a process that attempts to modify behavior by positive and negative reinforcement. Therefore, through operant condition, an individual makes an association between consequences and behaviors. For example, telling a child to go to his room is a punishment frequently used to avoid the cursing.

Chart 4 – Forms of operand conditioning to human behavior

<table>
<tr><th></th><th>Positive</th><th>Negative</th></tr>
<tr><td rowspan="2">Reinforcement</td><td rowspan="2">add appetitive stimulus</td><td>Escape
remove noxious stimuli</td></tr>
<tr><td>Active Avoidance
avoid noxious stimulus</td></tr>
<tr><td>Punishment</td><td>add noxious stimuli</td><td>remove appetitive stimulus</td></tr>
</table>

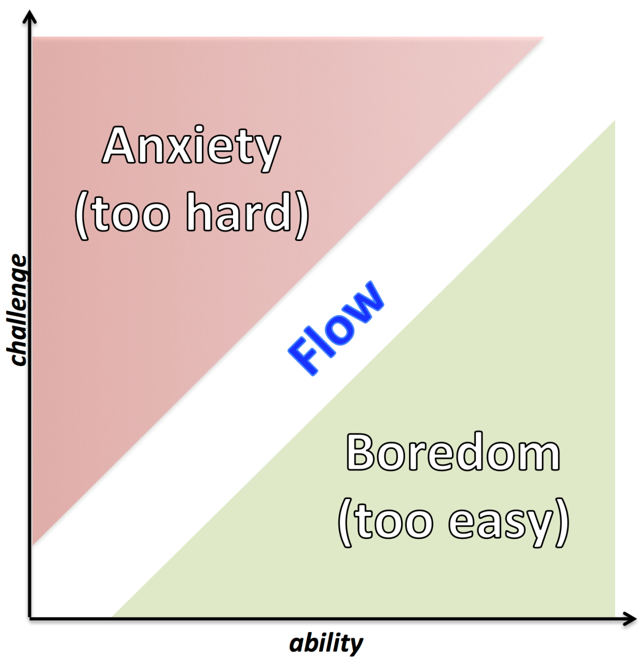
Source: Elaborated by the author.

In this sense, the reinforcement and punishment as shown in Chart 4 are operant conditioning that come in two forms: positive and negative. As we can see in this table, the negative reinforcement has two forms, one related to remove the noxious stimuli (escape) and other related to avoid the stimuli (active avoidance).

2.2.4.3 Csikszentmihalyi's Flow Theory

Csikszentmihalyi's flow theory constitutes an important theory regarding the study of affective states during active activities for intrinsic purposes, such as discussions, exercises, and learning activities (SNYDER; LOPEZ; PEDROTTI, 2010; CSIKSZENTMIHALYI, 2014). Passive activities like listening music or watching TV usually do not need individuals to actively do something. The flow theory describes the experiences of intrinsically motivated persons in tasks chose for its own sake. Thus, this theory states that in order for a task to be fully engaging it must reach an optimal mind state named flow, which is a state of optimal intrinsic motivation, full concentration, absorption and intense immersion (WU, 2011; XU, 2011). In other words, if a user is in flow state during the performance of a task, he or she feels naturally in control and neither overwhelmed by difficulty nor uninterested. The users in flow state experience a loss of self-awareness, forgetting about time, worry, ego and physical symptoms.

Figure 10 – Graph of the three-flow channel model



Source: Adapted from Csikszentmihalyi (2008).

It is not a simple task to reach a flow state, and according to the flow theory, the following conditions must be satisfied to achieve the flow state:

- Clear goals, in which the expectations and rules are clearly discernable.

- Direct and immediate feedback, in which the successes and failures of task are apparent, so that behavior can be adjusted as needed.
- Good balance between ability level and challenge.

In the flow theory, the most important condition is accomplishing and maintaining the right balance between difficulty and ability to do some task. There must be enough challenge so that the user will not become bored but not so much that the user will feel frustrated by the complexity (CSIKSZENTMIHALYI, 2008). This delicate equilibrium is denominated as flow channel and is depicted on Figure 10.

The ability to create the flow state in games and game-like systems as gamification is essential to engagement users in these applications (XU, 2011). However, it is typically challenging to create activities that induce the right balance between ability and difficulty that matches all users of an application.

2.2.5 Persuasion and Persuasive Design Models

Persuasion as a practice is as old as human existence, and it is defined as the process of influencing changes of peoples' beliefs, attitudes, intentions, and motivations toward target behaviors (SEITER; GASS, 2004). Human-to-human persuasion was broadly researched since early 400 BC when Aristotle defined rhetoric as "… *the faculty of observing in any given case the available means of persuasion*" (NATANSON, 1955). Thus, there are many persuasive models that are concentrated on addressing aim to change the mental state of the persuades through communication (GUERINI; STOCK; ZANCANARO, 2007). In the last decade, many researches pointed out that similar to a human persuader, computing technologies can be used to produce changes in human behaviors, beliefs, attitudes, intentions, and motivation in various ways of designing technology to influence these changes in different contexts, such as sports (HARJUMAA; Segersta ahl; Oinas-Kukkonen, 2009), health (ORJI; VASSILEVA; MANDRYK, 2014), and education (LUCERO *et al.*, 2006; GOH; SEET; CHEN, 2011).

In this section, an overview of most relevant persuasive design models to develop computer as persuasive technologies, defined as Captology (FOGG, 2002), is summarized below.

2.2.5.1 Fogg's Behavior Model

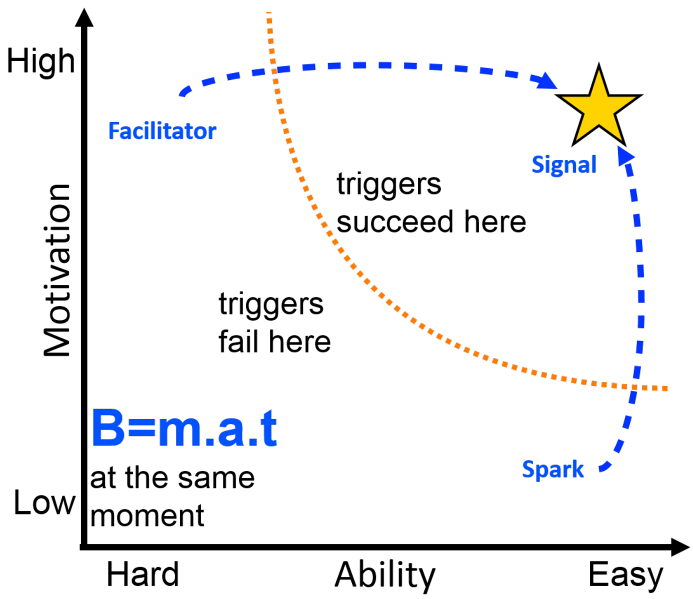
According to Fogg (2009), for a behavior to occur, the motivation, ability, and trigger must converge at the same moment reaching the activation threshold. Figure 11 depicts the Fogg's behavior model, in which the components of model (motivation, ability, and trigger) show that, to pass the activation threshold and trigger the behavior, an event or task must be motivating and not too difficult. In this sense, the three components of Fogg's behavior model are defined as follows:

- *Motivation* is the process used to allocate energy in actions to maximize the satisfaction of needs (PRITCHARD; ASHWOOD, 2008). In this process, energy is the time and effort available to meet those needs, and needs are the magnet that drives motivation. Thus, motivation can be measured by the degree in which someone is willing or engaged in performing the behavior (XU, 2011).

- *Ability* is the degree to which someone has the skills or tools to carry out the behavior (XU, 2011). There are six factors that work together in the context of a trigger to define the ability, these factors are: time, money, physical effort, brain cycles, social deviance, and non-routine.

- *Trigger* is what prompts people to take a behavior. The trigger is also known with different names such as cue, prompt, call to action, request, and so on. The trigger is related to the degree to which someone is provoked to perform the behavior (XU, 2011). Sometimes a trigger can from our daily routine (e.g. walking through the kitchen may trigger us to open the fridge), other times the triggers can be external, such as alarms, messages, and so on.

Figure 11 – Visual depiction of Foog's Behavior Model



Source: Adapted from Fogg (2009).

When a target behavior does not occur, at least one of those three factors is missing, or one is not enough sufficient to attain the activation threshold. The fact, if the individual has a high motivation to accomplish the task, but if he/she does not have the ability to perform it, the behavior will not occur. On other hand, if the individual lacks motivation to perform a target behavior, this behavior does not occur. Having the ability and motivation alone are not enough to cause a behavior, people need triggers that them "*to complete the action in a certain moment*"

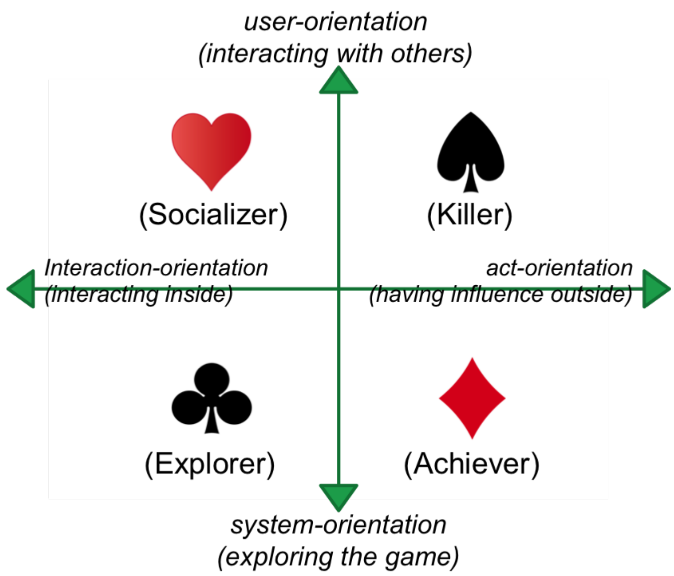
2.2.6.1 Player Types Models

The term game player (or player, for simplicity) is frequently used to describe individuals who play games, and there are different types of game players. There are people who take gaming seriously, playing full-fledged games a significant part of their daily lives. These players refer themselves as serious or hardcore gamers (BOSSER; NAKATSU, 2006). On the other hand, casual gamers are people ranging from occasional game players (KUITTINEN *et al.*, 2007). Based on characteristic that players exhibit within games such as competitiveness, sociability, exploratory behaviors, and individual personality traits, (LAWS; JACKSON, 2002; NACKE; BATEMAN; MANDRYK, 2014; BARTLE, 2004; MARCZEWSKI, 2013) identify different player typologies.

Three main typologies of player types deeply explored in this dissertation are summarized below.

Bartle's player types (BARTLE, 2004; BARTLE, 1996) is the most popular classification of four-player types based on preferences of persons when they are playing a game. By studying players of the Multi-User Dungeon (MUD) game, Bartle (2004) identifies four players types (achievers, socializer, explorer, and killers) as shown in Figure 13, in which there are two dimension of 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 these preferences, the four player types are defined as follows:

Figure 13 – Bartle's model of four-player types



Source: Adapted from Bartle (2004).

- *Achievers*: These players in general play games to win, they are goal-oriented players with great sense of achievement. The gameplay experience of this player type is driven by goals that either explicitly stated by the game (for example, gathering coins, or leveling up) or personally created (for example, accumulating much money or exclusive items).

- *Socializers*: These players are driven by communication and relationship. Socializers interacting with others players using communication tools provided by the game, and they find the greatest reward in what the others players have to say about them in the games.
- *Explorers*: These players like interact with the world, and they are driven by finding new areas and gaining new knowledge about the virtual world. The activities that a player of this type may like to include things like: exploring every corner of a map, finding interesting features such as bugs, and understanding how everything functions.
- *Killers*: These players act on other players to obtain enjoyment by attacking, killing or causing anxiety on others. Players of this player type like imposing themselves on the game to dominate others. For example, a player who likes to obtain powerful weapons to attack other players with the goal of killing the characters of other players is a killer.

Yee's Motivational Components (YEE, 2006b; YEE, 2006a) is a model of player type developed by Nick Yee who devised an experiment based on Bartle's four player types by conducting an extensive survey of Massive Multiplayer Online Role-Playing Games (MMORPGs) players for 3200 individuals who answered 39 multiple-choice questions. Based on the results of this experiments, he derived ten motivational components grouped in three main components as shown in Chart 5, where the main components are independent of each other.

Chart 5 – Motivational components revealed by the factor analysis in the Yee's experiment

Achievement (*mastery need*)	**Social** (*relatedness need*)	**Immersion** (*autonomy need*)
Advancement progress, power, accumulation, status	**Socializing** casual chat, helping others, making friends	**Discovery** exploration, lore, finding hidden things
Mechanics numbers, optimization, templating, analysis	**Relationship** personal, self-disclosure, find and give support	**Role-Playing** story line, character history, roles, fantasy
Competition challenging others, provocation, domination	**Teamwork** collaboration, groups, collaboration, groups,	**Customization** appearances, accessories, appearances, accessories, style, color schemes
		Escapism relax, escape from reality avoid reality problems

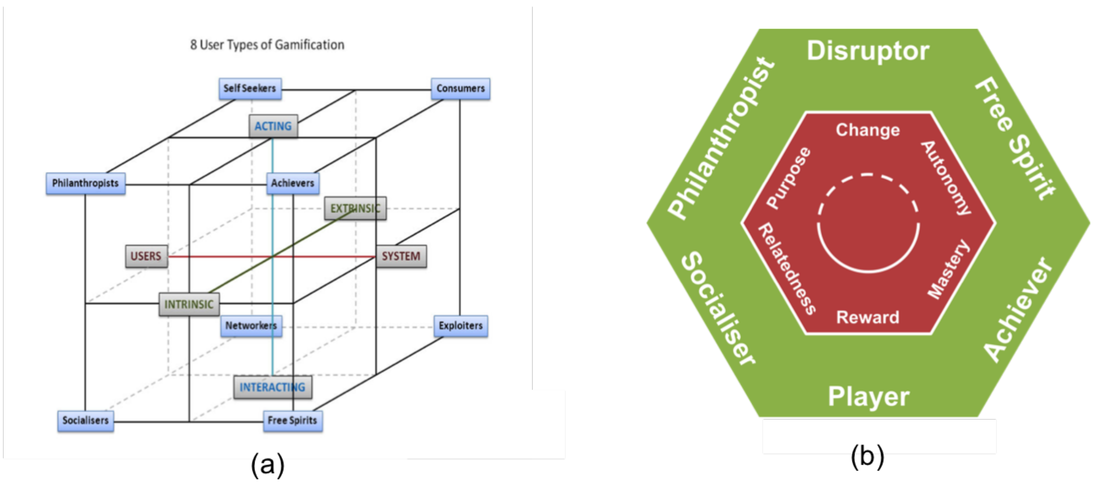
Source: Adapted from Yee (2006b).

With the SDT theory as background and the mapping showed in Chart 5 (autonomy need for achievement component, mastery need for immersion component, and relatedness need for social component), Yee (2006a) points that Bartle's player types conflicted with the results analyzed through factor analysis. He states that socializing and role-playing are two independent motivations, while Bartle proposed that people who like chat and make friends are also people who like to role-play. While Bartle proposed that achievers and griefers (killers) are separate types, there is correlation between advancement and competition that defines the desire of achievers and killers, respectively. The explorer defined by Bartle as people who enjoy both exploring the world and gathering information is in reality two different kinds of people defined by the two separate factors: discovery, and mechanics. Finally, the immersion component is a motivation that did not exist in Bartle's type.

These motivations are not solely for MMORPGs but they are also applicable to other game-like systems such as gamification. Through the incorporation of these principles, a gamified system will induce larger amounts of user engagements. However, it does not define a component related with the purpose need widespread by the theory proposed by Pink (2011). The purpose need is a general class of need that varies from person to person, it is behind all 10 components.

Marczewski's player types (MARCZEWSKI, 2015a; MARCZEWSKI, 2015c) expands the Bartle's model through the addition of one dimension related with type of motivation (intrinsic motivation, extrinsic motivation). As show in Figure 14 (a), Marczewski describes eight player types, four of whom are intrinsic motivated (socializer, free spirits, achiever and philanthropists) and four extrinsic motivated (networker, exploiter, consumer and self seeker). According to Marczewski (2013), Bartle's player types is useful but flawed, at the end, a gamified system is not a MUD game where all users want to participate, and rewards plays an important role to define whom can be engaged with extrinsic motivators like badges and trophies.

Figure 14 – Marczewski's eight-playe and six-player types models



Source: Adapted from Marczewski (2013).

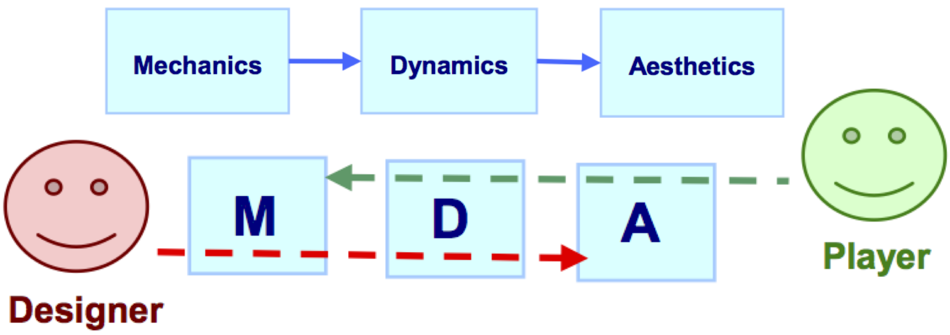
Based in the four needs defined in SDT theory (DECI; RYAN, 2010) and the theory proposed by Pink (2011) (Relatedness, Autonomy, Mastery, and Purpose), Marczewski redefines the eight-player types model to six-player types model as shown in Figure 14 (b). He defines four basic intrinsic player types: Achiever, Socializer, Philanthropist, and Free Spirit that are respectively motivated by relatedness need, autonomy need, mastery need, and purpose need.

Next, the player type *player* groups the extrinsic player types (Self-seeker, Consumer, Networker, and Exploiter) as the players who are motivated by rewards. They will do similar thing to the intrinsic motivated player types, buy only if there is a reward at the end of it. Finally, the player type *disruptor* is a group of players that act in a system motivated by change. They like to disrupt a system in some way, and rather than a single type, this player type is a group, in which there are four types: Griefer, Destroyer, Influencer, and Improver that are related with Philanthropist, Achiever, Socializer, and Free Spirit, respectively.

2.2.6.2 MDA model

In game design, the Mechanics-Dynamics-Aesthetics (MDA) model (HUNICKE; LEBLANC; ZUBEK, 2004) as shown in Figure 15 is a tool used to analyze game-like systems. It formalizes the consumption of games by breaking them down into mechanics, dynamics, and aesthetics, in which the *mechanics* are the base components of the game, its rules, and elements related with basic action that a player can take in the game, such as algorithms and data structures. The *dynamics* are the run-time behavior of the mechanics acting on player input. The *aesthetics* are the emotional responses evoked in the player, such as challenge, discover, fantasy, and fellowship.

Figure 15 – MDA Model: Mechanics, Dynamics and Aesthetics model



Source: Hunicke, LeBlanc and Zubek (2004).

According to this model, the mechanics itself is not as important inside a game-like system as the dynamics and aesthetics. The authors of MDA model state that "*thinking about games as designed artifacts helps frame them as systems that build behavior via interaction*." Thus, a game-like system must provide multiple aesthetics depending on its goals. Therefore, it is important that the dynamics correspond with the aesthetics to provide an optimal environment in which the player can develop the desired behaviors, attaining the goals of game-like system. In this sense, Bunchball (2010) propose a framework of gamification showed in Figure 16 that sets the relationship between game mechanics and human desires (aesthetics in MDA model).

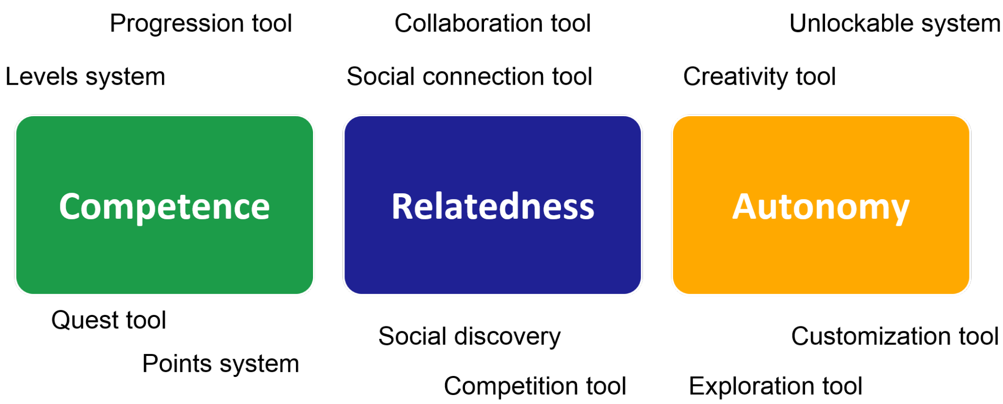
In the same way of the framework proposed by Bunchball (2010), as shown in Figure 17, we can define the relationship between some game elements and the psychological needs defined in the SDT theory. Thus, the competence need is excellently supported by game elements, such as

Figure 16 – Human desires vs. Game mechanics

Source: Bunchball (2010).

progression tool, levels system, and point system, because they contain sophisticated mechanics that provide granular and timely feedback in term of indicators to satisfy the competence need. The relatedness need is satisfied by social interactions that have always been an important part of game-like systems through the game elements such as collaboration tool, social connection tool, social discovery, and competition tool. As the most of games placed players in the role of fictional characters providing a wide range of in-game choices through the game elements such as unlockable system, creativity tool, customization tool, and exploration tool, these elements provide support to satisfy the need of autonomy.

Figure 17 – Relation between game elements and SDT theory



Source: Elaborated by the author.

2.2.6.3 Persuasive Game Design Models

Developing persuasive technology in the form of games has become a common practice. These types of games referred as persuasive games have been designed with the the primary purpose of changing players' behaviors, feelings, or thoughts. In the last decade, several persuasive games have been developed by researchers as a novel approach to modifying users' behaviors. For example, "*What Remains*?" is a persuasive game in which using stories are used to personalize the Alzheimers' patients care giving (CADAMURO; VISCH, 2013), "*Smoke*?" is a persuasive game aimed to support players in smoking cessation (KHALED *et al.*, 2007), and "*OrderUP*!" is a persuasive game that motivates healthy eating habits (GRIMES; KANTROO; GRINTER, 2010).

Despite the growing interest of researchers in using and develop persuasive games, little attention has been given to develop models that would help the designers to design persuasive games and/or tailored these games to increase their efficacy at achieving their intended objective of motivating behavior change. In the following paragraphs, a model-driven persuasive game design proposed by (ORJI; VASSILEVA; MANDRYK, 2014) is summarized.

Model-driven Persuasive Game Design: It is a model developed following the steps indicated in the model-driven approach to persuasive game design proposed by (ORJI, 2014). This model consists in guidelines for tailoring persuasive games based on the BrainHex player-type model (NACKE; BATEMAN; MANDRYK, 2014). Therefore, the best and worst persuasive strategies, as shown in Chart 6, for each one of the seven player types of BrainHex model were identified in the Model-driven persuasive game design.

Chart 6 – Best and worst persuasive strategies for the player types of BrainHex model

Player Type	Best strategy	Worst strategy
Achiever	**Cooperation**, reward, self-monitoring, and suggestion	
Conqueror	**Competition and comparison**, simulation, personalization, self-monitoring and suggestion	
Daredevil	**Simulation**	**Self-monitoring and suggestion**, competition and comparison
Mastermind	**Self-monitoring and suggestion**, competition and comparison, personalization, simulation, customization	
Seeker	**Customization**, personalization, competition and comparison, praise	
Socializer	**Cooperation**, competition and comparision	**Self-monitoring**, praise, customization
Survivor	**Self-monitoring and suggestion**, competition and comparision	**Cooperation**, reward, customization

Strategies presented in order of strength (bold are the higest)

Source: Adapted from Orji (2014).

providing greater semantic precision and ensuring the fidelity and consistency of concepts about a target world.

In this dissertation, we will develop the ontology OntoGaCLes as a heavyweight ontology, and application ontology for the domain of gamified CL scenarios.

2.3.3 Ontology Representation

Nowadays, the ontologies can be represented in two ways, one representation is the formal representation that is used for computer consumption, and another representation is the graphical representation for human comprehension.

2.3.3.1 Formal Representation

To allow the formal representation for a direct computer consumption, there are many languages that have been proposed using the predicate logics, description logics or frame based languages. The most popular language and framework to describe ontologies is the Web Ontology Language (OWL) language that is based on the Resource Description Framework (RDF)/RDF-Schema.

The RDF specification was developed by the World Wide Web Consortium (W3C) for metadata description. It is formally represented in the eXtensible Markup Language (XML) employing triplets that contain a subject node, predicate, and object node (<subject, predicate, object>). Each node in the triplet can be a web resource (URI reference), a value (literal) or a document identifier (to represent a blank node). A set of triples also can become a node itself, and a property is a semantic relation between nodes (subject and object).

To represent triplets, the RDF/RDF-Schema specifications define classes, properties, and relationships that can be used to describe these triples as statements about resources. It also includes definition of tags and hierarchical structures (taxonomy) providing the basic elements for the description of ontologies. However, the RDF-Schema has some limitation, especially to support computational reasoning on data available through the internet (Patel-Schneider, 2005). Thus, the OWL specification provides an expressive language to develop ontologies.

OWL is a language developed and endorsed by the W3C to satisfy the formalism for the Semantic Web (SW). It allows the SW applications to understand and answer queries of agents (people or other programs) by reasoning on Web content by ontological descriptions. OWL was developed based on DAML+OIL (HORROCKS; others, 2002) with a formal specification influenced by description logics, the frames paradigms and the OWL exchange syntax (namely RDF/XML) (HORROCKS; Patel-Schneider; van Harmelen, 2003).

There are three variants of OWL referred as OWL Lite, OWL DL and OWL Full. These three variants allow to achieve a good balance between scalability and expressive power. According to the OWL specification, each variant is an extension of its simpler predecessor. Thus, OWL Lite is used manly for classification hierarchy and simple constraints; OWL DL gives maximum expressiveness retaining computational completeness and decidability; and OWL Full gives maximum expressiveness, however with no computational guarantees, the reasoning process using OWL Full may not be completed in a finite time. Figure 20 shows as example part of an ontology to represent the formalization of bicycle in OWL language.

Figure 20 – Part of bicycle ontology in the OWL

```
<owl:Class rdf:ID="Vehicle">
    <rdfs:label>Veiculo</rdfs:label>
    <rdfs:subClassOf rdf:resource="#Any" />
</owl:Class>
<owl:Class rdf:ID="sport_cycle">
    <rdfs:label>Bicicleta_Esportiva </rdfs:label>
    <rdfs:subClassOf rdf:resource="#bicycle" />
</owl:Class>
<owl:Class rdf:ID="city_cycle">
    <rdfs:label>Bicicleta_Urbana</rdfs:label>
    <rdfs:subClassOf rdf:resource="#bicycle" />
</owl:Class>
<owl:Class rdf:ID="bicycle">
    <rdfs:label>bicicleta </rdfs:label>
    <rdfs:subClassOf rdf:resource="#Vehicle" />
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:cardinality rdf:datatype="http://www.w3.org/
            <owl:onProperty rdf:resource="#has_body_color" />
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource="#has_body_color" />
            <owl:allValuesFrom rdf:resource="#Color" />
```

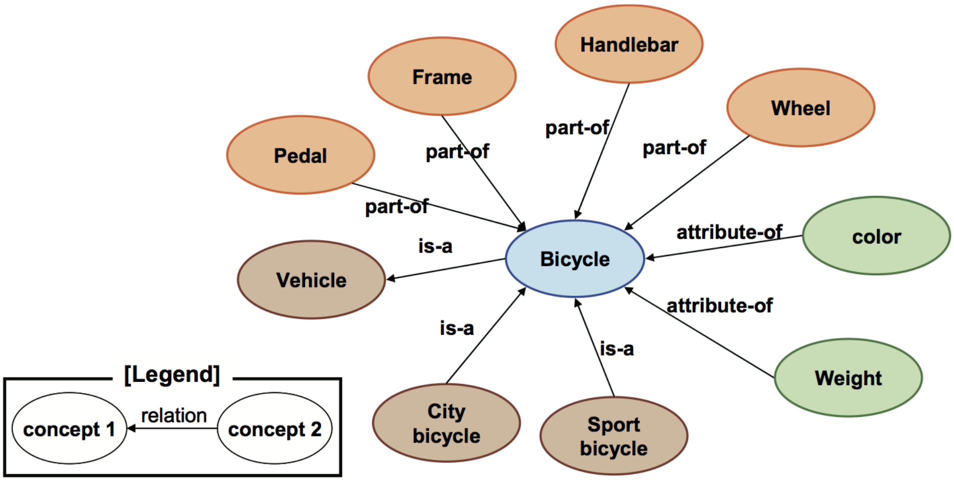
Source: Isotani (2009).

As the author of this dissertation used the graphical representation to describe the ontological structures, details of the RDF/RDF-Schema and OWL languages are not detailed in this section. The RDF/RDF-Schema and OWL are automatically generated by graphical ontology editors, such as Protégé (NOY *et al.*, 2001), OntoEdit (SURE *et al.*, 2002) and Hozo (KOZAKI *et al.*, 2002).

2.3.3.2 Graphical representation

As an ontology is mainly composed by concepts and their relations, the graph is a common representation of ontologies, where the nodes represent concepts and the arrows represent relations between concepts (DIENG; HUG, 1998). Figure 21 shows the graphical representation of an ontology referred to bicycle. In this ontology, the concept of a bicycle is a specialization of vehicle represented using *is-a* relation (<bicycle *is-a* vehicle>). In this ontology, the class “*City bicycle*” and “*Sport bicycle*” are related to the class “*Bicycle*” by the arrows "*is-a*" to indicate that the bicycle is specialized into sport bicycle and city bicycle, and the class "*Bicycle*" is associated to the class "*Vehicle*" by the arrows "*is-a*" to indicate that vehicle is a super-class of the class bicycle. The attributes "*Color*" and "*Weight*" are indicated by the arrows "*attribute-of*." Finally, the arrows "*part-of*" indicate the elements that compose a bicycle, and these elements are: *Wheel*, *Handlebar*, *Frame*, and *Pedal*. The scheme of colors in this figure helps the reader identify the relationship between concepts.

Figure 21 – A graph representation of a bicycle ontology



Source: Isotani (2009).

Although the representation of ontologies using graphs is the most common, it suffers deficiencies that do not help to capture important elements in an ontology (DEVEDŽIC, 2006), especially when trying to represent the model of roles proposed by Mizoguchi *et al.* (2007).

To deal with the modeling of ontologies based on the model of role, the Hozo ontology editor (KOZAKI *et al.*, 2002) has been proposed as an authoring environment in which the differentiating of basic concepts (e.g. human, and artifact) from role concepts (e.g. learner, and reward) is described as frames diagrams. In this graphical representation based on frames, to deal with the concept of role, the following three classes are defined:

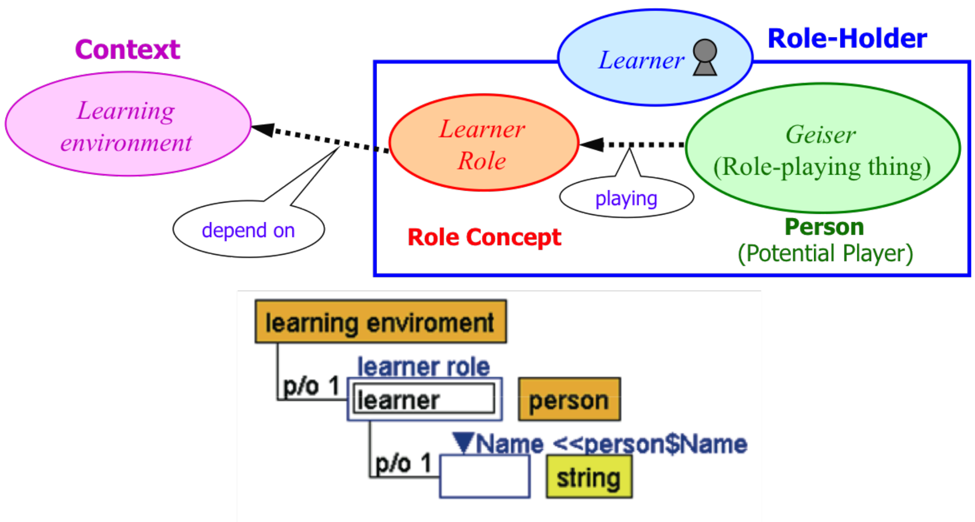
Role concept - A concept representing a role that depends on a context (e.g. learner role that depends on the school);

Basic concept - A concept that does not need other concepts to be defined (e.g. human); and

Role holder - An instance of a base concept that is holding the role (e.g. learner).

The basic concepts are used as class constraints, and the instances that satisfy the class constraints play the role, becoming role holders. For example as shown in the Figure 22, "In a learning environment there is a vacancy for a learner, and a person, whose name is Geiser, fills the position, becoming a learner in the particular environment." The person who plays a role is referred as a role holder. Thus, *Geiser* becomes a *learner* in the *learning environment* by playing the *learner role*. The top of the figure shows how the concepts around a role are related to each other and in the bottom is shown the representation in Hozo.

Figure 22 – The learner role holder in Hozo representation



Source: Elaborated by the author.

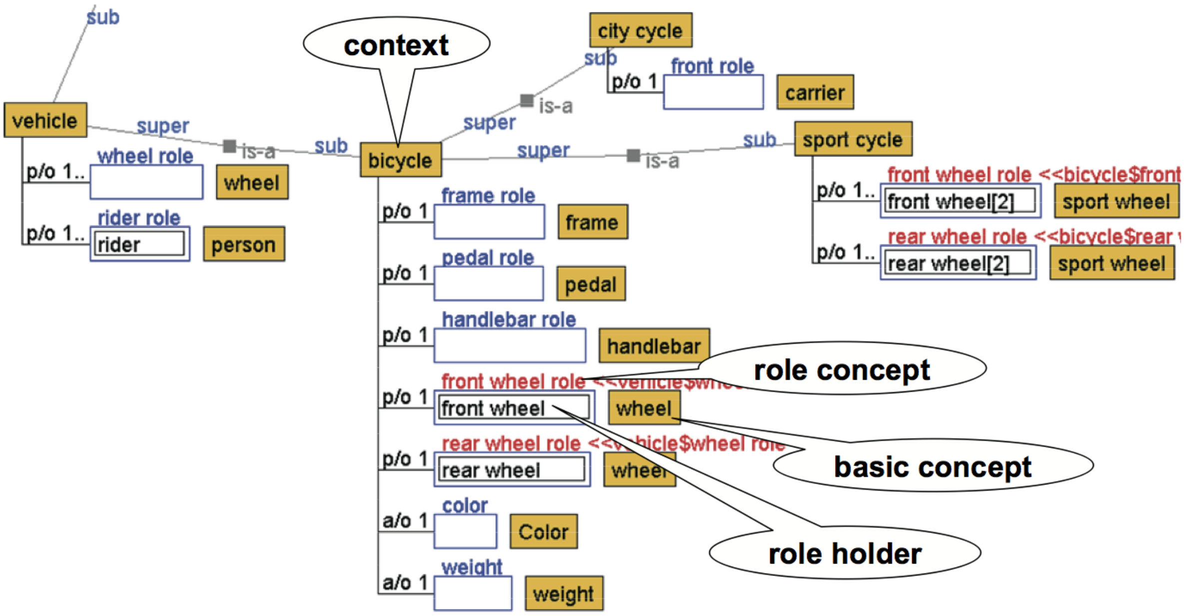
Figure 23 shows the representation of bicycle ontology using Hozo representation. In this figure, the relations part-of and attribute-of is respectively represented by labels "*p/o*" and "*a/o*" that appear in front of each slot. Thus, the frame, pedal, handlebar, and wheels are part of the bicycle. Observe that in the context of bicycle, a wheel (basic concept) can play the role of front wheel or rear wheel (role concepts). Thus, a particular instance of a wheel that plays one of these roles (front wheel role or rear wheel role) is referred to as role holder. In summary, a front wheel is an instance of wheel playing the front wheel role.

2.3.4 Ontology Engineering

Ontology engineering encompasses a set of activities conducted during the conceptualization, design, implementation and deployment of ontologies (DEVEDZIĆ, 2002; DEVEDŽIC, 2006). It covers topics including philosophy, metaphysics, knowledge representation formalisms, development methodology, knowledge sharing and reuse, knowledge management, business process modeling, common sense knowledge, systematization of domain knowledge, information retrieval from the Internet, standardization, and evaluation.

Developing ontologies is a time-consuming and difficult task that requires knowledge about the target domain, theoretical background on ontology formalization, and the skills to properly define the concepts and elements as body of knowledge in ontologies. Thus, to facilitate the development of ontologies, there are several formal methodologies and methods that have

Figure 23 – Example of bicycle ontology using Hozo representation



Source: Isotani (2009).

been proposed. The guidelines of these methodologies and methods are categorized into three layers shown in Figure 24 (MIZOGUCHI, 2004a), in which:

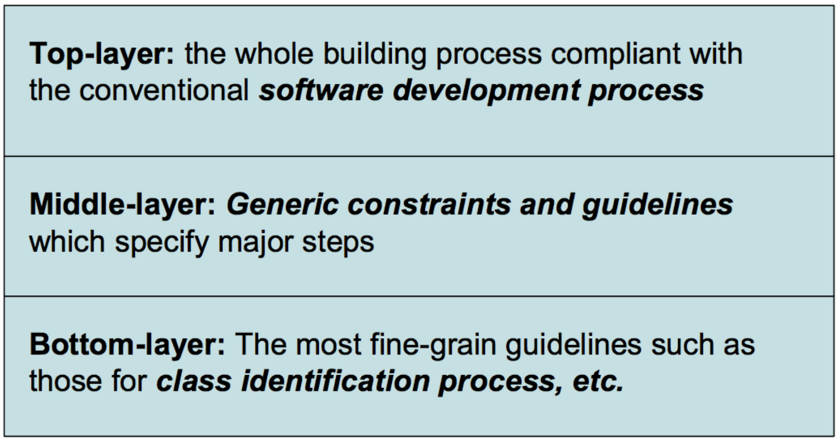
1. **Top-layer** contains the coarsest level of guidelines that specifies the whole building process with standard software development life cycles. The guidelines described in this layer correspond to ontological methods and methodologies associated with conventional software development processes and practices.

2. **Middle-layer** describes the generic constraints and guidelines that specify a set of major steps and their order of execution. In each step of middle layer, the detailed information about the activities to be completed, and the way for each activity should be carried out.

3. **Bottom-layer** corresponds to the most fine-grain guidelines that enable the construction of concepts hierarchy. It describes guidelines to create explicit semantic structures from identified concepts in the target world.

Most of the currently existing methods and methodologies describe guidelines concerned mainly with the top-layer. Some examples are METHONTOLOGY (Fernandez-Lopez; Gomez-Perez; JURISTO, 1997), On-To-Knowledge (SURE; STAAB; STUDER, 2004), and Ushold and King's methodology (USCHOLD; KING, 1995). Unfortunately, only a few of them deal with the middle and bottom layers. The main problem of having few methodologies for the development of the middle and bottom layers is that the chances of creating a good ontology at the end of some process decreases.

Figure 24 – Three-layer classification model of guidelines proposed in methodologies and methods to develop ontologies



Source: Mizoguchi (2004a).

In this sense, Mizoguchi (2004a) proposed a set of guidelines to support the development of ontologies at the middle and bottom layers based the Activity-First Method (MIZOGUCHI, 1995), and in this dissertation, the author of this dissertation utilized these guidelines to create the ontology OntoGaCLeS. Therefore, the rest of this section presents an overview of guidelines (MIZOGUCHI, 2003; MIZOGUCHI, 2004b; MIZOGUCHI, 2004a) that were summarized by Isotani (2009) as described as follows:

Middle Layer Guidelines

1. Identify concepts rather than terms. As ontology is totally independent of terminological problems, one cannot stress the importance of this distinction too much. Since people will be easily trapped by the endless terminological discussion departing from the underlying conceptual structure of the target domain.
2. Use mixed and flexible strategies of top-down, bottom-up and middle-out. Never stick to only one of the strategies.
3. Whenever possible, identify and use top-level ontology in the early phase of the development process to govern the rest of the steps.
4. When you deal with a concept, identify its main components, using "*part-of*" relation as well as its main attributes. You can thus find and extend candidates of concepts to be included in the ontology.
5. Definition of axioms should be done after finishing is-a hierarchy building and informal term definition.
6. Note that you cannot define any concept completely in theory. Therefore, do not stick to the definition of each term too much. At the best, you only can give necessary conditions

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

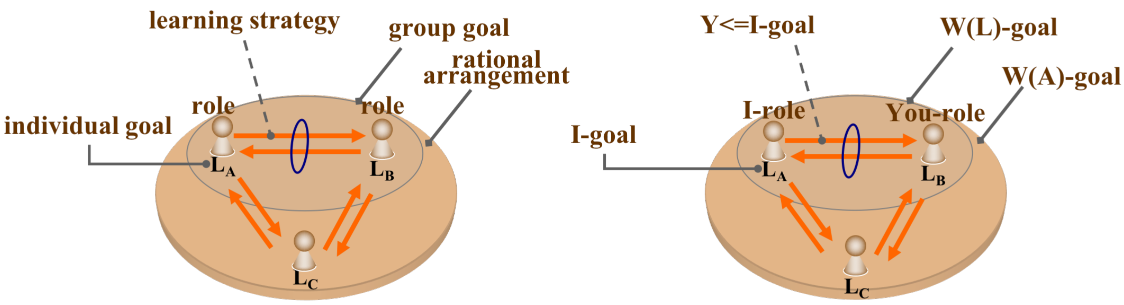
You-role is the CL role played by the participant (*You*) who is interacting with the participant in focus (*I*).

Y<=I-goal is the learning strategy employed by the participant in focus (*I*) to interact with the participant (*You*) in order to achieve his/her individual learning goals (*I-goal*).

W(L)-goal is the common learning goal for the group members in the CL scenario.

W(A)-goal is the rational arrangement of the group activity used to achieve the common learning goal (*W(L)-goal*) and the individual learning goals (*I-goal*).

Figure 25 – Concepts, terms and relations defined in the CL Ontology

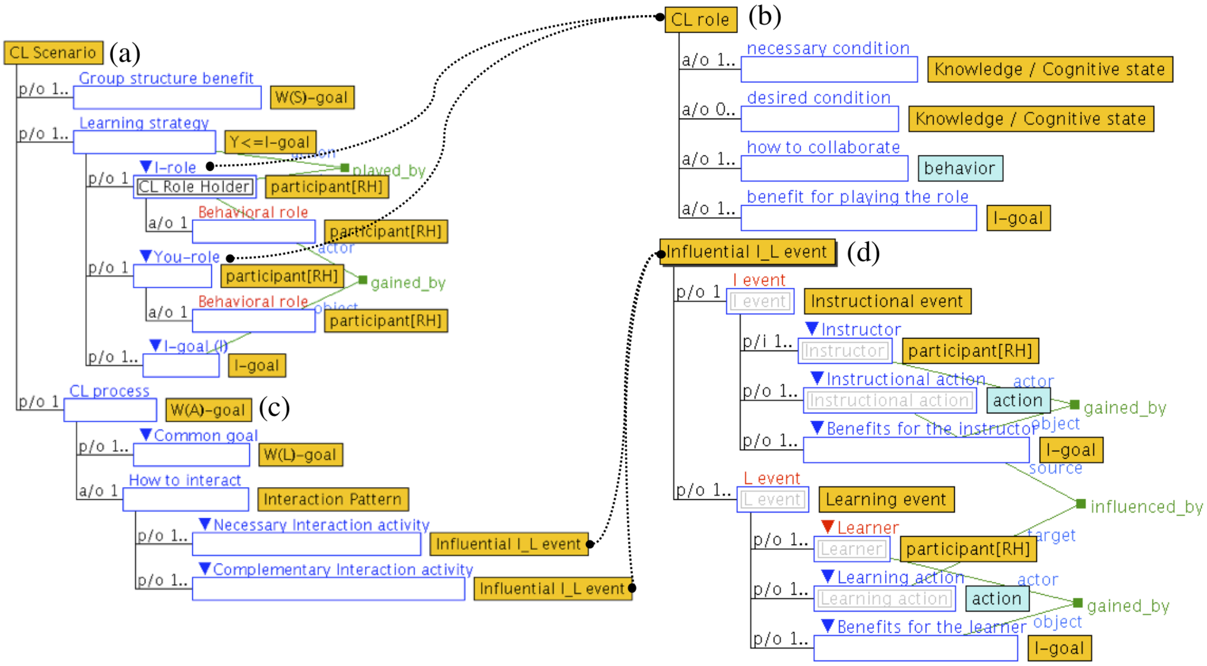


Source: Isotani (2009).

To express the relationship of concepts described above, the CL Ontology employs the ontological structures shown in Figure 26 to represent CL scenarios. In these ontological structures, a CL scenario is represented by three parts defined as: the *Group structure benefit* (*W(S)-goal*) to describe the expected benefits of the structured collaboration (i.e. positive interdependence, individual accountability, promotive interactions); the *Learning strategy* (*Y<=I-goal*) to describe the learning strategies employed by the group members in the CL scenario; and (3) the *CL process* to describe the rational arrangement of the group activity (*W(A)-goal*).

(a) The **Learning strategies** (*Y<=I-goal*) are guidelines that specify how the participants should interact with others members of group to achieve their individual goals. These guidelines help the group members to externalize a desired behavior to play a given CL role more adequately. Therefore, the Learning strategy is represented as an ontological structure composes by: the participant in focus (*I*) who plays the CL role "*I-role*", the participant (*You*) who interacts with the participant in focus (*I*) playing the CL role "*You-role*," and the individual learning goals (*I-goal*) that are expected to be achieved by the participant in focus (*I*) at the end of CL scenario. The *behavioral role* as part of the CL roles "*I-role*" and "*You-role*" is used to describe the behaviors externalized by the participants "*I*" and "*You*" when they interact in the CL scenario employing the learning strategy (*Y<=I-goal*).

Figure 26 – Ontological structure to represent CL scenarios



Source: Isotani (2009).

(b) The **CL role** describes functions, goals, duties and responsibilities that must be taken by members of group to achieve the common and individual learning goals. Thus, the ontological structure to represent a CL role is composed by: the *necessary condition* and *desired conditions* to play the CL role, the description of *how to collaborate* when a group member plays the CL role, and the description of *benefits for playing the role*. In this ontological structure, *Cognitive/Knowledges states* are used to define the necessary and desired conditions for a group member to play the CL role, *behaviors* are used to describe *how to collaborate* playing the CL role, and individual learning goals (*I-goal*) are employed to describe the expected *benefits for playing the role*.

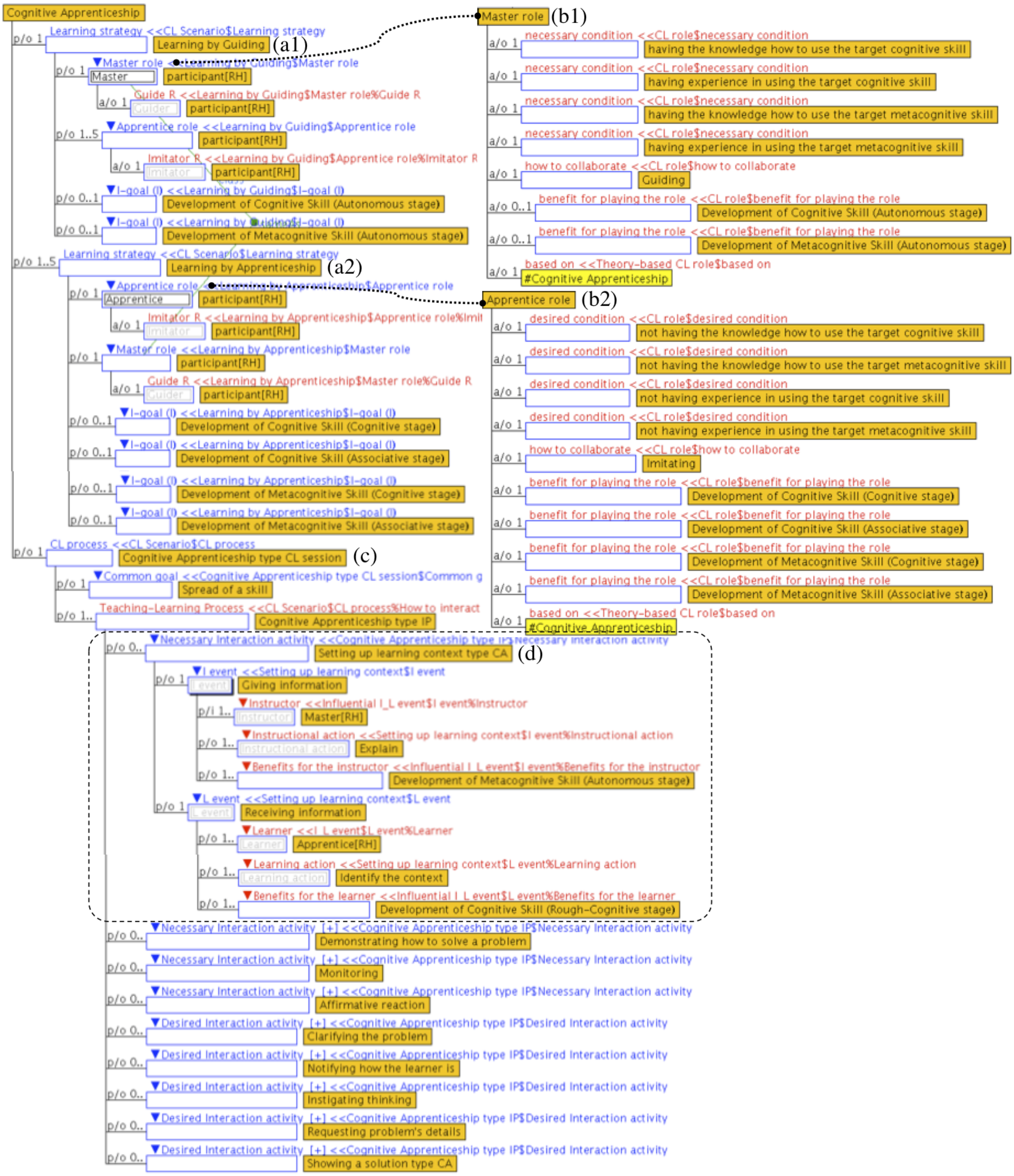
(c) The **CL process** is the *rational arrangement of group activity* (*W(A)-goal*) whereby the common and individual learning goals are achieved by the group members. This arrangement is represented by the *common learning goals* (*W(L)-goal*) as result of the negotiation process in the group formation, and by the *Interaction Pattern* as the sequencing mechanism followed by the participants to achieve their individual learning goals (*I-goal*). The interaction pattern is represented as a set of *necessary* and *desired interactions* in which the interaction for the group members is described as influential Instructional-Learning events (*Influential I_L events*).

(d) The **Influential I_L event** represents the interaction among the group members and the benefits obtained by the interaction from two viewpoints: from the viewpoint of participants who play a role of instructor, and from the viewpoint of participants who play a role of learner. The influential I_L event describes group members performing actions that influence other members with the purpose to change their own learning states by helping others to achieve their individual learning goals. Therefore, the ontological structure to represent an influential I_L event is composed by two events: a *learning event* and an *instructional event* in which the participants are represented as actors of CL scenario playing CL roles and performing a set of actions to achieve their individual learning goals (*I-goal*). For a group member acting as *instructor*, the influential I_L event describes his/her interaction with other group member who acts as *learner* by means of instructional actions, and the expected *benefits for the instructor* (*I-goal*). For a group member acting as *learner*, the influential I_L event describes his/her interaction with other group member who acts as *instructor* by means of learning actions, and the expected *benefits for the learner* (*I-goal*).

As it was said before, the ontological structures shown in Figure 26 are used to describe CL scenarios that compliant with instructional and learning theories. To illustrate this, Figure 27 shows the representation of a CL scenario based on the Cognitive Apprentice theory. According to this theory, the CL activities should incorporate situations that are familiar to those who are using these activities, and these situations must to lead the participants to act and interact acquiring skills in a specific context, and then generalizing these skills to other situations. Therefore, the CL scenarios based on the Cognitive Apprentice theory focuses on supporting a more skilled participant (known as *master*) to teach a familiar situation for the lesser skilled participants (known as *apprentices*) who learn by observing the skilled participant's behaviors and mimic him/her in other similar situations. From the viewpoint of the more skilled participant, he/she is supported by the learning strategy "*learning by guiding*" (a1), his/her role (*I-role*) is the *Master role* with a behavioral role of *Guider*, and his/her individual learning goals are the *development of cognitive* or *meta-cognitive skills* at the levels of *Autonomous stage*. From the viewpoint of a lesser skilled participant, he/she is supported by the learning strategy "*learning strategy by guiding*" (a2) to interact with the master, his/her role (*I-role*) is the *Apprentice role* with the behavioral role of *Imitator*, and his/her individual goals are the *development of cognitive* and/or *meta-cognitive skills* at the levels of *Cognitive stage* and *Associative stage*.

According to the cognitive apprentice theory, the more skilled participant who plays the master role must have knowledge and/or experience in using the target cognitive or metacognitive skill. Therefore, the necessary conditions to play the *Master role* as shown in Figure 27 (b1) are: *having the knowledge how to use the target cognitive skill*, *having experience in using the target cognitive skill*, and *having experience in using the target metacognitive skill*. When a participant adequately plays the master role, he/she acts *Guiding* others participants, and as consequence of this behavior, he/she is benefited with the *Development of cognitive or metacognitive skill* at the *Autonomous stage*. The cognitive apprenticeship theory indicates that the participants without any knowledge or experience in how to use the target skill should play the apprentice

Figure 27 – Ontological structures to represent a CL scenario based on the cognitive apprenticeship theory

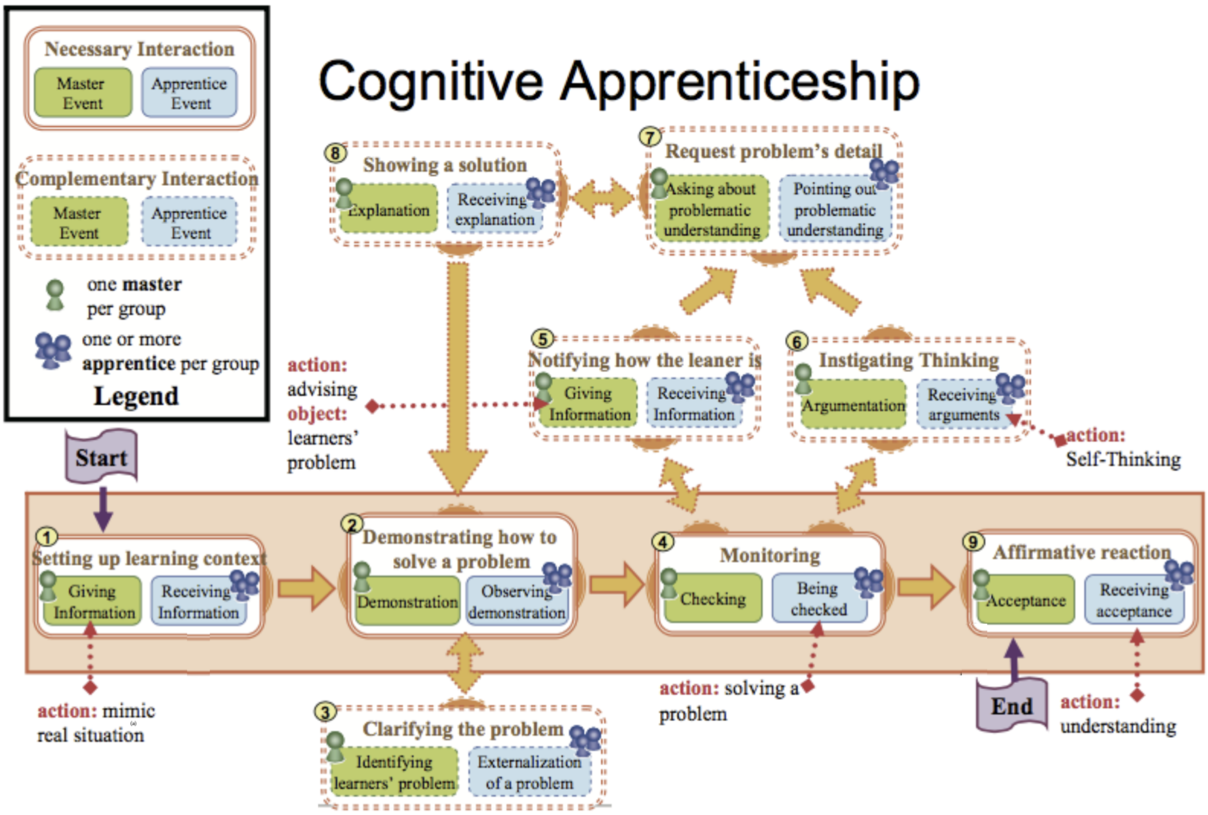


Source: Elaborated by the author.

role. Therefore, there is not necessary conditions in the ontological structure shown in Figure 27 (b2) to represent the *Apprentice role*, and the desired conditions for this role are: *not having the knowledge how to use target metacognitive or cognitive skill* and *not having experience in using the target metacognitive or cognitive skill*. When a participant adequately play the *Apprentice role*, he/she acts *Imitating* the behavior of the master and obtaining the benefits in the *Development of metacognitive or cognitive skill* at the levels of *Cognitive* and *Associative* stages.

When the two learning strategies, *Learning by Guiding* and *Learning by Apprenticeship*, are simultaneously employed to structure the interactions among the participants in the CL scenario, a positive synergy is created among them producing a *Spread of skills*. This arrangement is formalized by the ontological structure shown in Figure 27 (c), where the *CL process* is defined as a *Cognitive Apprenticeship type CL session*, the *Common goal* of this session is the *Spread of skill*, and the *Teaching-Learning Process* is an *Interaction Pattern* defined by the sequencing mechanism of a CSCL script inspired by the Cognitive Apprenticeship theory. This sequencing mechanism defines the necessary and complementary interactions shown in Figure 28.

Figure 28 – Necessary and complementary interactions defined by the sequencing mechanism of a CSCL script inspired by the cognitive apprenticeship theory



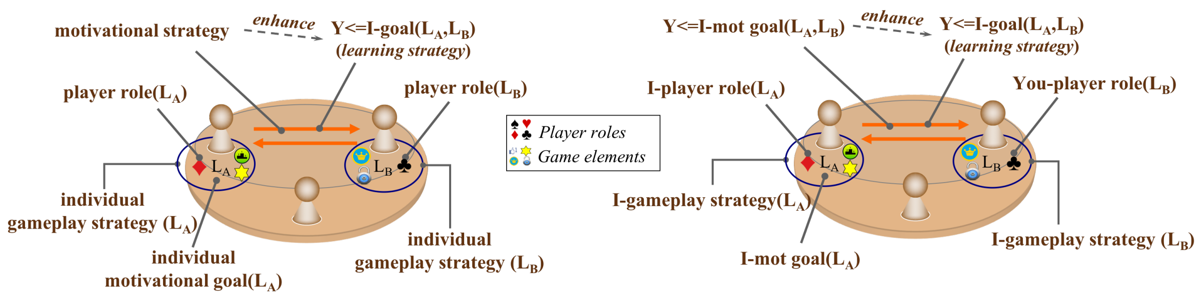
Source: Adapted from Isotani (2009).

The necessary and desired interactions defined by the sequencing mechanism shown in Figure 28 are formalized as *Influential I_L event* in the *Teaching-Learning Process* of *Cognitive Apprenticeship type CL session* shown in Figure 27 (c). The ontological structure to represent the interaction "*Setting up learning context type CA*" is shown in detail in Figure 27 (d). In this interaction, the instructional event "*Giving Information*" describes the action "*Explain*" as an instructional action performed by the participant who plays the *Master role* to *develop the metacognitive skill* at the level of *Autonomous stage*. The learning event "*Receiving information*" describes the action "*Identify the context*" as a learning action performed by the participant who plays the *Apprentice role* to *develop the cognitive skill* at the level of *Rough-Cognitive stage*.

3.2 Ontological Structures to Represent Gamified Collaborative Learning Scenarios

The concepts, terms and relations shown in Figure 29 have been formalized in the ontology OntoGaCLeS to represent gamified CL scenarios. These elements employ an independent vocabulary from any theory and practice, and they are described as follows as:

Figure 29 – Concepts, terms and relations defined in the ontology to represent gamified CL scenarios



Source: Elaborated by the author.

Y<=I-mot goal is the *individual motivational strategy* used to enhance the learning strategy (*Y<=I-goal*) employed by the participant in focus (*I*).

I-mot goal is the *individual motivational goal* for the participant in focus (*I*), and it represents what is expected to happen in his/her motivational stage when an individual motivational strategy (*Y<=I-mot goal*) is applied in the CL scenario to enhance the learning strategy (*Y<=I-goal*) employed by him/her to interact with other member of group (*You*).

I-player role is the *player role* for the participant in focus (*I*).

You-player role is the *player role* for the participant (*You*) who interacts with the participant in focus (*I*).

I-gameplay is the *individual gameplay strategy* for the participant in focus (*I*), and it describes the implementation of the individual motivational strategy (*Y<=I-mot goal*) when this strategy corresponds to the gamification.

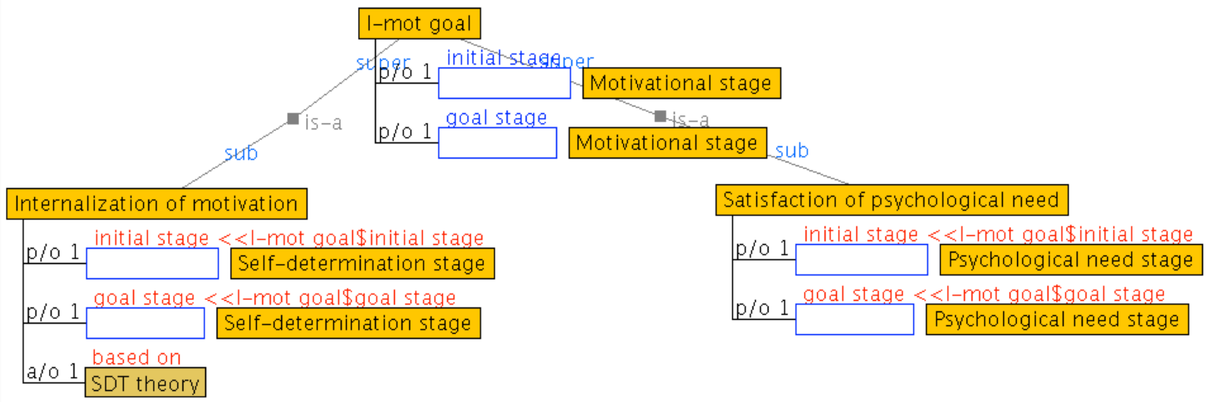
In the following subsections, the formalization of concepts, terms and relations briefly introduced here are detailed.

3.2.1 Individual Motivational Goal (I-mot goal)

The *individual motivational goal* (*I-mot goal*) has been formalized in the ontology OntoGaCLeS to represent the reason why is necessary to apply an individual motivational strategy in a CL scenario. Thus, for the participant in focus (*I*), the individual motivational goal (*I-mot goal*) represents what is expected to happen in his/her motivational stage when a motivational strategy is applied in the CL scenario to enhance the learning strategy employed by him/her to interact with others. In this sense, the individual motivational goal describes the motivational stages that must be reached by a person to be motivated to interact with other.

Figure 30 shows the ontological structure that has been formalized in the ontology OntoGaCLeS to represent an individual motivational goal (*I-mot goal*), where: the *initial stage* and *goal stage* are stages used to represent the expected change in the motivational stage of the person in focus (*I*).

Figure 30 – Ontological structures to represent individual motivational goal (*I-mot goal*). At the bottom, the "*Satisfaction of psychological need*" (left) and the "*Internalization of motivation*" (right)



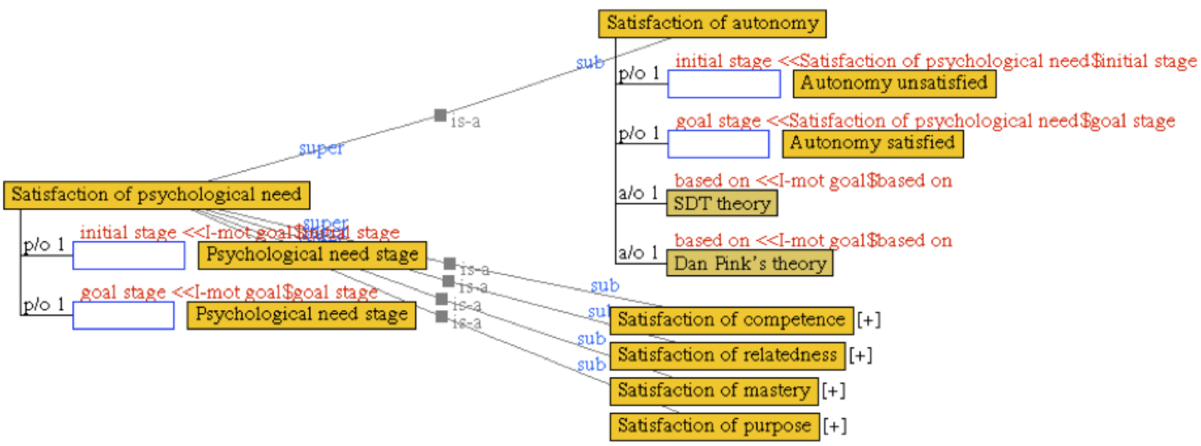
Source: Elaborated by the author.

Two types of individual motivational goals have been currently formalized in the ontology OntoGaCLeS to describe the individual motivational goals (*I-mot goal*) related to gamification as individual motivational strategy. The former, known as *Satisfaction of psychological needs*, has been formalized based on the conceptualization of motivation as internal psychological process to satisfy human needs (PRITCHARD; ASHWOOD, 2008); and the latter, known as *Internalization of motivation*, has been formalized based on the form in which an individual regulates his/her own choices to behave and act (DECI; RYAN, 2010). Figure 30 shows the representation for these two types of individual motivational goals. The initial and goal stages related to the *Internalization of motivation* are defined by the self-determination stage, whereas the initial and goal stages for the *Satisfaction of psychological need* are defined by the *psychological need stages*. In the articles

(CHALLCO *et al.*, 2015; CHALLCO *et al.*, 2014; CHALLCO *et al.*, 2014), the author of this thesis used the concept of "*Phychological need*" to refer the concept of "*Psychological need stage*," and the concept of "*Without need*" to refer the stages described as "*$1 need satisfied*" where $1 is substitute by psychological needs (e.g. *Mastery need satisfied*).

As it was mentioned before, in the Chapter 2, motivation is an internal psychological process associated with three general components of arousal, direction and intensity in which the arousal component is caused by needs (also called *wants* or *desires*). These needs cause that a person behaves and acts to satisfy needs (MITCHELL; DANIELS, 2003). Consequently, motivation is a constructor that describes why a person chooses to allocate time and energy for different behaviors and actions to maximize the satisfaction of his/her own needs (PRITCHARD; ASHWOOD, 2008). It means that, in a CL scenario, the motivation problem caused by the scripted collaboration occurs when the participant believes that this scenario will not lead him/her to satisfy his/her individual needs. Therefore, the motivational strategy is applied in the CL scenario to change this perception. Based on this assumption, the individual motivational goals (*I-mot goal*) for the person in focus (*I*) has been formalized in the ontology OntoGaCLeS as the satisfaction of needs. More specifically, in gamified CL scenarios, the individual motivational goal is described as *Satisfaction of psychological needs* because game elements do not satisfy all human needs, they only satisfy part of these needs that are referred by the author of this thesis as *psychological needs*. The psychological needs are the human needs that are classified in the groups of relatedness and growth needs according to the ERG (Existence, Relatedness and Growth) theory (ALDERFER, 1972).

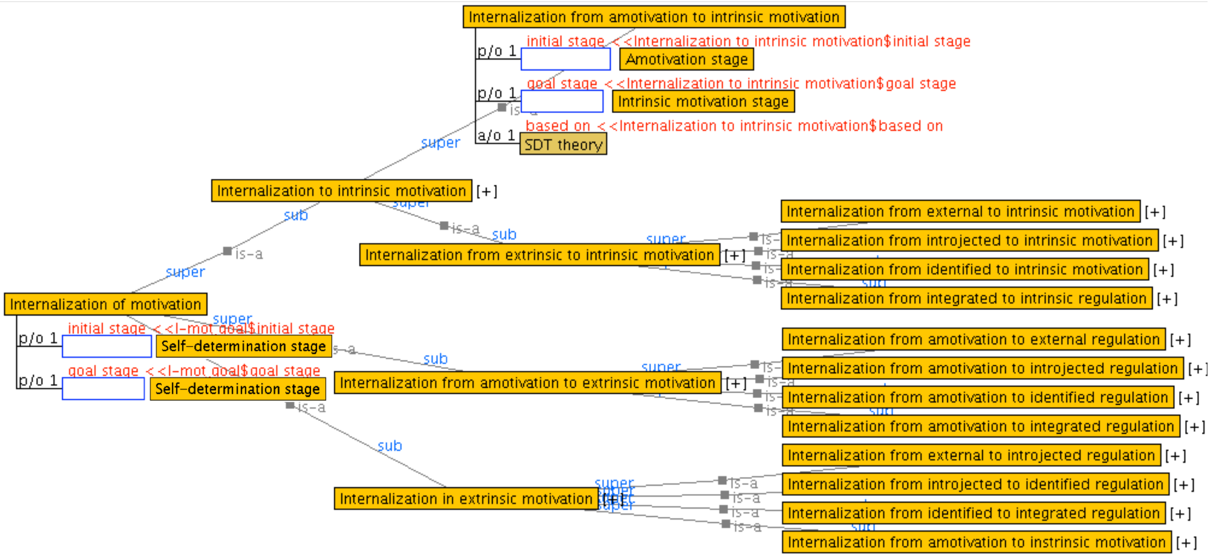
Figure 31 – Ontological structures to represent "*Satisfaction of psychological need*." At the top right, the ontological structure to represent "*Satisfaction of autonomy*."



Source: Elaborated by the author.

Figure 31 shows the ontological structures formalized to represent the *Satisfaction of psychological need*. These ontological structures represent the satisfaction of innate psychological needs, and they comprise what is intended to evoke in minds of users by the majority of experts when non-game contexts are gamified (MORA *et al.*, 2015; SEABORN; FELS, 2015). According to the SDT theory (RYAN; DECI, 2000; DECI; RYAN, 2010), the well-being of an individual is reached when the psychological needs of autonomy, competence and relatedness are satisfied (DECI; RYAN, 1985; DECI; RYAN, 2010), and according to the Dan Pink's theory (PINK, 2011), a person is motivate and engage in a cognitive, decision-making, creative or higher-order thinking task when it is given with autonomy, mastery and purpose. At the top right of Figure 31, the ontological structure to represent the *Satisfaction of autonomy* is detailed in which, based on a unipolar scale from unsatisfied need to satisfied need, the roles for the initial and goal stages are played by the *Autonomy unsatisfied* and the *Autonomy satisfied*, respectively. Employing the same unipolar scale, and the need-theories of motivation, SDT theory (DECI; RYAN, 2010) and Dan Pink motivation theory (PINK, 2011), a set of individual motivational goals as satisfactions of psychological needs have been formalized in the ontology OntoGaCLeS, and they are detailed in section A.2.

Figure 32 – Ontological structures to represent "*Internalization of motivation*." At the top right, the ontological structure to represent the "*Internalization from amotivation to intrinsic motion*."



Source: Elaborated by the author.

The *internalization of motivation* is the process by which "*values, attitudes or regulatory structures, such that the external regulation of a behavior is transformed into an internal regulation, so no longer requires the presence of an external contingency*" (GAGNÉ; DECI, 2005). In this sense, the internalization of motivation in relation to the satisfaction of needs refers to changes in the motivation from a non-free choice to a free choice of needs that are satisfied by oneself. According to the SDT theory (DECI; RYAN, 1985; RYAN; DECI, 2000), this change happens from the extrinsic motivation to intrinsic motivation when motivation is changed from a non-self-determined form (*non-freely choice*) to a self-determined form (*freely choice by oneself*). Here, the extrinsic motivators employed by the game elements must be configured as an attempt to transform the current motivation stages of participants from amotivation and extrinsic motivation into intrinsic motivation. Based on these definitions, the ontological structures shown in Figure 32 have been formalized in the ontology OntoGaCLeS to represent the *Internalization of motivation*. These ontological structures have been formalized employing the continuum ranging of stages from *amotivation* (not internalized behave) into *external motivation* (not at all internalized behave) to *introjected motivation* (partially internalized behave) to *identified motivation* (fully internalized behave) to *intrinsic motivation* (automatically internalized behave). At the top right of Figure 32 is detailed the formalization for the change from *Amotivation stage* (*initial stage*) to *Intrinsic motivation stage* (*goal stage*) defined as "*Internalization from amotivation to intrinsic motivation*." The detailing of all ontological structures to represent the internalization of motivation is presented in section A.2.

3.2.2 Player Role

The identification of homogeneous people groups that differ from other groups in a significant way is essential to define the personalization in any system. In game design, this segmentation is established by player types models in which typologies are used to categorize the users in different groups according to their geographic location (Ben Judd *et al.*, 2016; CHAKRABORTY *et al.*, 2015), their demographic situation (GREENBERG *et al.*, 2010; SHAW, 2012), their psychographic characteristics (TSENG, 2011; YEE, 2006b), and their behavioral characteristics (BARTLE, 2004; LAZZARO, 2009). These player type models aim to help the game designers to identify the necessary features that make a game fun, enjoyable and desirable for a particular audience.

The player type models cannot be directly extrapolated to others context for which they are not intended. Thus, the concept of *Player role* has been formalized by the author of this thesis in the ontology OntoGaCLeS to define typologies of player types in the context of CL scenarios. Player roles describe the functionality, responsibilities and requirements whereby a group of participants becomes players in a gamified CL scenario. This segmentation is based on individual characteristics of participants that establish a segmentation of participants using necessary and desired conditions. In this sense, the *Player role* has been formalized by the ontological structure shown in Figure 33. This structure defines the conditions that must be satisfied by a participant in the CL scenario to play the player role as: *necessary condition* and *desired condition*. Thus, a participant of CL scenario cannot play a player role when he/she does not fulfill the necessary conditions, and when the participant fulfills the necessary and desired conditions has more probability to obtain the expected *benefits for playing the role*.

The necessary and desire conditions in the ontological structure to represent *Player role* are defined by: motivation states, psychological need states, and individual personality trait states. A tree overview for these states are detailed in section A.1, where:

- The *motivation state* is an internal state that describes the temporal attitudinal state of a person in relation to his/her desire to be a participant in the CL session. These stages can be

Not motivated and *Motivated*. The state of motivated is also divided in two types: "*Intrinsic motivated*" and "*Extrinsic motivated*" (DECI; RYAN, 2010). It is important to notice here that the concept of motivation state is not the same as the concept of motivation stage. Although both concepts represent changes in relation to the motivation of participants, the motivation state represents a specific point in the whole process of being motivated, whereas the motivation stage represents an interval in the motivation process.

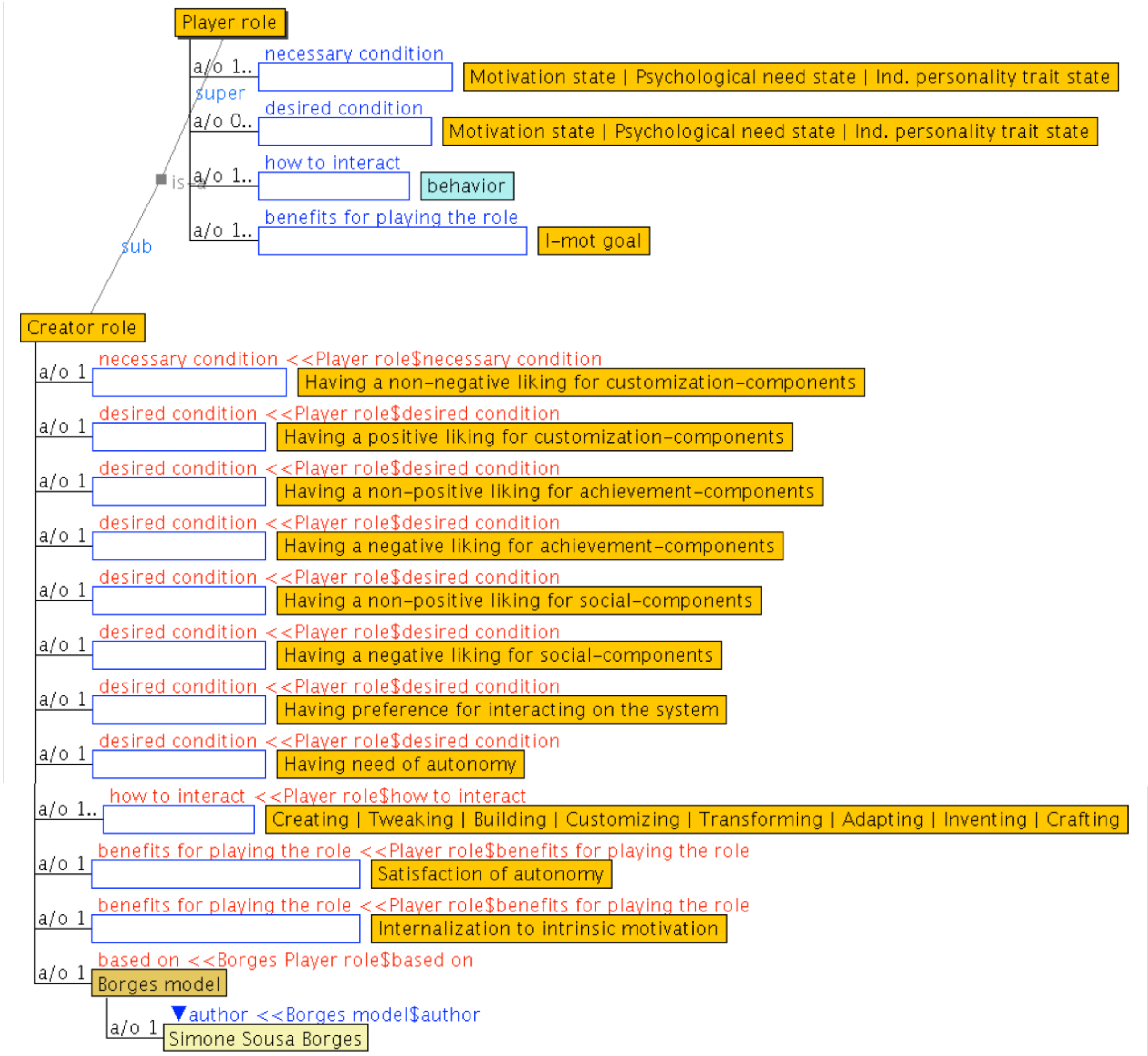
- The *psychological need state* represents the current psychological need of a person in which the states for each one of the psychological needs are formalized through the representation of pair states: "*Having need of $1*" and "*Not having need of $1*" in which "*$1*" is replaced by the name of the need that is being described as prerequisite. For instance, to represent the states related to the psychological need of competence, the states of "*Having need of competence*" and "*Not having need of competence*" have been formalized as psychological need state in the ontology OntoGaCLeS.

- The *individual personality trait state* describes states related to individual personality traits, such as introversion, extraversion, openness to experience, and conscientiousness. The individual personality trait states describe the characteristic that make a person unique by indicating his/her habitual patterns of thought, emotion and behavior for different situations (MATTHEWS; DEARY; WHITEMAN, 2003). These states express whether a participant either has or does not have the individual personality trait. In the ontology OntoGaCLeS, there are represented individual personality traits states related to: the big five personality traits (COSTA; MACCRAE, 1992), the MBTI personality traits (BRIGGS, 1976), the game-playing style preferences described in the Bartle's player type model (BARTLE, 2004), and the game-playing liking preferences described in the Yee's motivation components (YEE, 2006b).

Beside to describe the necessary and desired conditions that should be satisfied by an individual, the ontological structure to represent *Player role* shown in Figure 33 describe the information about: how the participant with the player role is expected to interact with the game elements (*how to interact*), and the expected benefits for playing the player role (*benefits for playing the role*). Thus, concepts described as *behavior* are used to represent the possible manners in which a participant should interact to other, and concepts described as individual motivational goals (*I-mot goal*) are used to represent the expected *benefits for playing the role*.

At the bottom of Figure 33, the *Creator role* is shown as example of the formalization of a player role using the ontological structure proposed in this section. According to this structure, participants who have a greater liking for customization-components rather than for other game components are classified as creators. This segmentation is represented by the necessary condition of "*having a non-negative liking for customization-components*," and the desired conditions of "*having a positive liking for customization-components*," "*having a non-positive*

Figure 33 – Ontological structure to represent “*Player role*” (At the top). At the bottom, the ontological structure to represent the player role “*Dreamer role*.”



Source: Elaborated by the author.

liking for achievement-component,” “*having a negative liking for achievement-component*,” “*having a non-positive liking for social-component*,” and “*having a negative liking for social-component*.” The desired conditions related to the behavioral characteristics of participants to act as a player role are: “*having preference for interacting on the system*” and “*having need of autonomy*.” The expected behaviors to obtain benefits for playing the creator role are: “*Creating*,” “*Tweaking*,” “*Building*,” “*Customizing*,” “*Transforming*,” “*Adapting*,” “*Inventing*” or “*Crafting*.” As consequence to behave as creator, the participants attain the *Satisfaction of autonomy* and the *Internalization to intrinsic motivation* (*I-mot goal*).

In the ontology OntoGaCLeS, based on the information extracted from five different player type models, twenty-six players roles have been formalized and represented using the ontological structure proposed in this section. These player roles, their conditions, expected behaviors and benefits for the person who plays the role are detailed in section A.3.

3.2.3 Individual Motivational Strategy (Y<=I-mot goal)

In the context of CL scenarios, an *individual motivational strategy* is defined by the author of this thesis as a set of guidelines defined to motivate a participant to interact with other group members using learning strategies. These guidelines are independent of any technology, so that the individual motivational strategy basically describes what motivates a participant to act and behave in certain way. For example, consider the following guidelines extracted from the Model-driven Persuasive Game in which:

> "... cooperation is only a significant motivator of behaviour change for achievers and socializers... This is in line with the gaming style of socializers, who enjoy helping others. Achievers would also prefer to cooperate because they are inherently more altruistic ... achievers do often co-operate with one another, usually to perform some difficult collective goal, and from these shared experiences can grow deep, enduring friendships which may surpass in intensity those commonly found among individuals other groups." Orji (2014).

When these two guidelines are applied in a CL scenario by providing a situation in which the participants must cooperate to achieve a group goal (e.g. obtain a especial reward based on the collective performance of group members), these guidelines becomes a individual motivational strategy that could be applied to motivate participant who fall in the category of socializer or achiever because they are motivated by the desired to accomplish the group goal and the desired to help others, respectively.

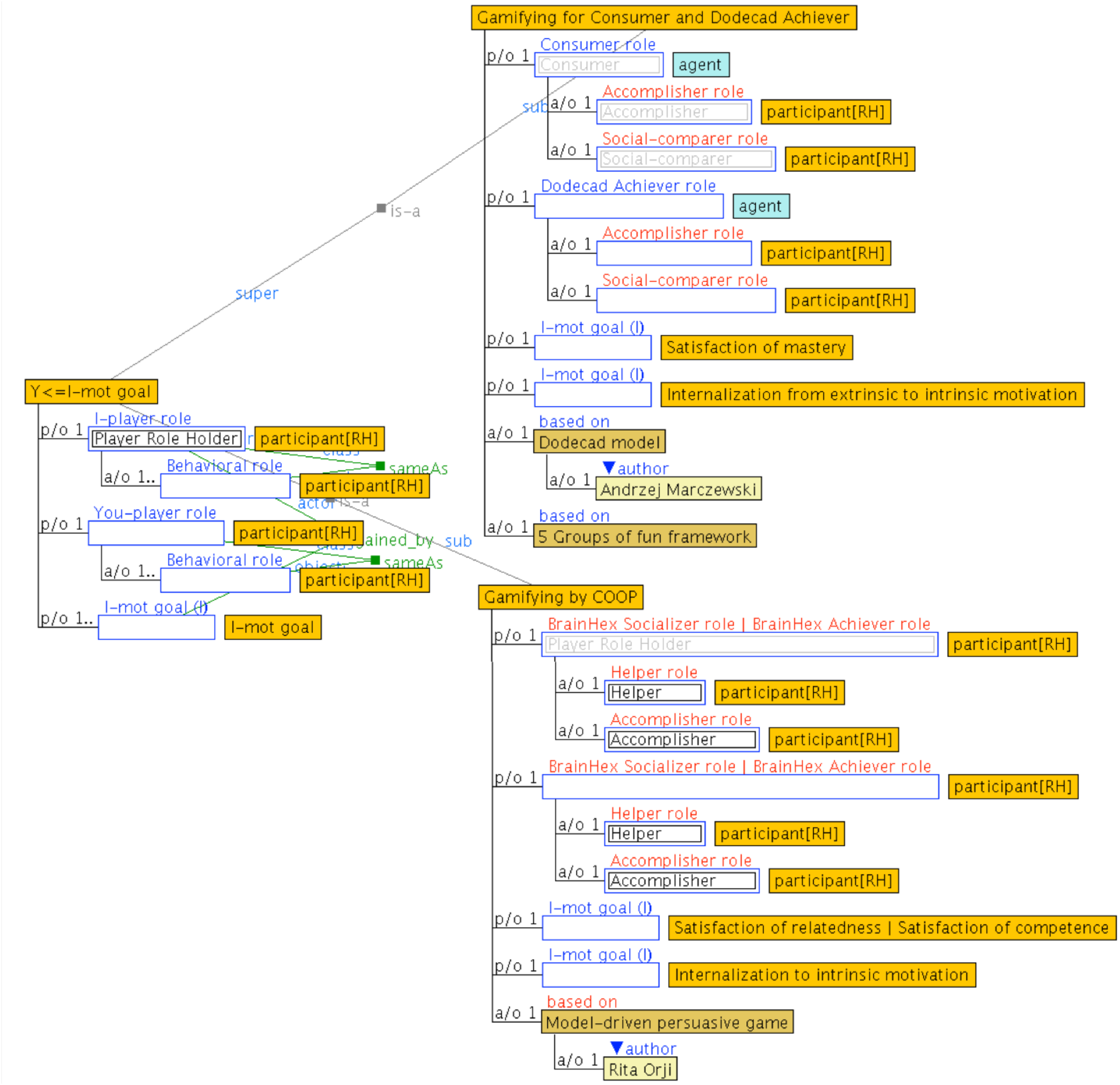
The ontological structure shown in Figure 34 has been proposed by the author of this PhD thesis dissertation to represent the formalization of individual motivational strategies whose guidelines are extracted from gamification models or game design models. According to this structure, an *individual motivational strategy* (*Y<=I-mot goal*) is described by:

I-player role to indicate the player role for the participant in focus (*I*) who becomes a *player role holder* when he/she is motivated by the motivational strategy. This player role also indicates the *behavioral roles* whereby the participant in focus (*I*) is motivated to interact with other participant (*You*) employing the learning strategy (*Y<=I-goal*).

You-player role to indicate the player role for the participant (*You*) who interacts with the participant in focus (*I*). The *behavioral roles* whereby the *player role holder* of this role supports the interaction of participant in focus (*I*) are also indicated in this structure.

I-mot goal (I) to indicate the individual motivational goals (*I-mot goal (I)*) whereby the participant in focus (*I*) is motivated to interact with other participant (*You*) employing a learning strategy (*Y<=I-goal*). In this sense, these individual motivational goals represent the reasons why the guidelines contained in the motivational strategy are applied in the CL scenario to enhance the learning strategy (*Y<=I-goal*) employed by the participant in focus (*I*) to interact with other participant (*You*).

Figure 34 – Ontological structure to represent "*Individual motivational strategy*" (at the left). At the right, the motivational strategies "*Gamifying for Consumer and Dodecad Achiever*" (right-top) and "*Gamifying by COOP*" (right-bottom).



Source: Elaborated by the author.

To exemplify the formalization of the individual motivational strategies using the ontological structure proposed in this section, Figure 34 also shows two examples in which the attribute "*based on*" indicates the gamification models in which these motivational strategies are based. The individual motivational strategy shown at the top-right of Figure 34 is known as "*Gamifying for Consumer and Dodecad Achiever*," and it has been formalized based on guidelines of the

Dodecad model (MARCZEWSKI, 2015a) and 5 Groups of fun framework (MARCZEWSKI, 2015b). According to these guidelines, the consumers and achievers are motivated by the need to obtain a reward that demonstrates for other participants their accomplishments. Hence, the *Accomplisher* and *Social-comparer* are *behavioral roles* whereby a participant in focus (*I*) playing the *Consumer role* is motivated to interact with the participant (*You*) who plays the *Achieve role*. Playing this role, the *Satisfaction of mastery* and the *Internalization from extrinsic to intrinsic motivation* are individual motivational goals whereby the participant in focus (*I*) as consumer is motivated to interact with other participant (*You*) who acts as achiever. Behaving as accomplisher and social-comparer, the participant in focus (*I*) has two individual motivational goals that are: to demonstrate his/her mastery represented as "*Satisfaction of mastery*;" and to internalize his/her current extrinsic motivation stage into intrinsic motivation stage represented as "*Internalization from extrinsic to intrinsic motivation*."

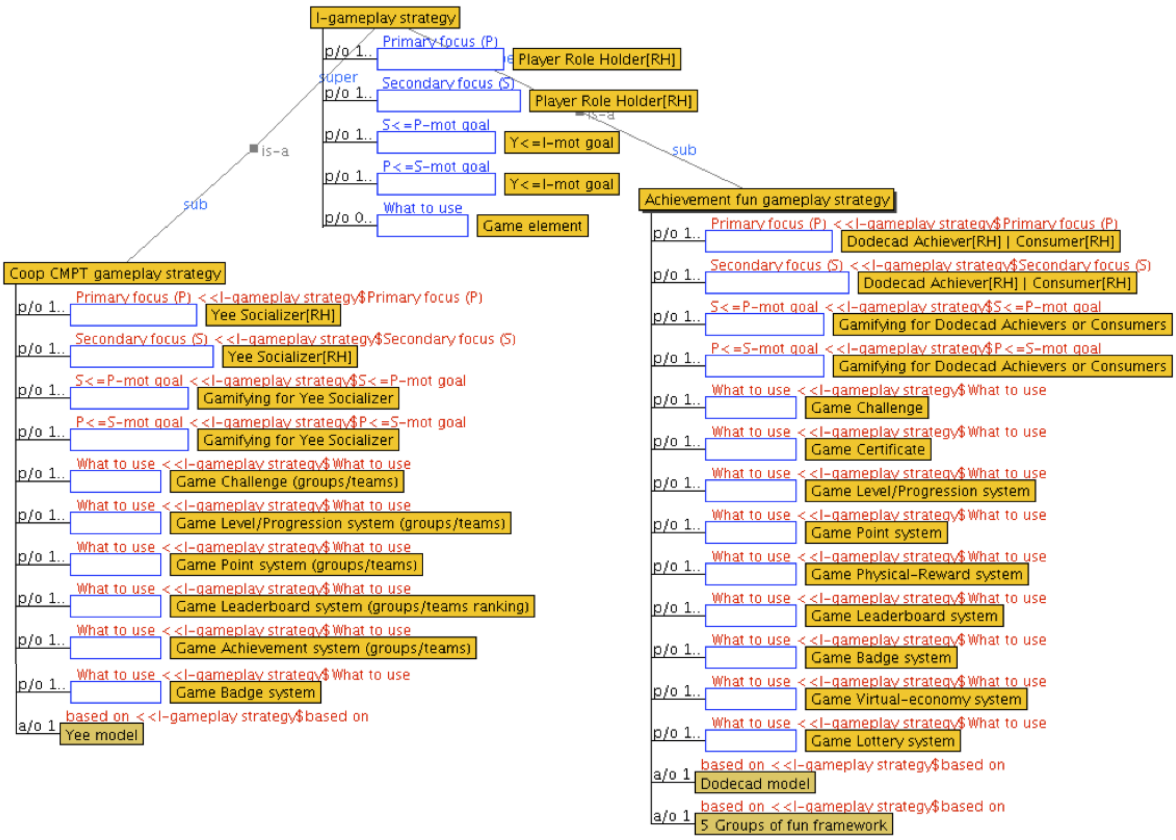
At the bottom-right of Figure 34, it is shown the ontological structure formalized to represent the application of the guidelines described in the Model-driven persuasive game for the cooperation strategy (ORJI; VASSILEVA; MANDRYK, 2014). These guidelines indicate cooperation as significant motivator for a participant who plays the socializer or achiever role because a participant who plays these roles enjoys to help others and cooperate with others in order to accomplish a difficult collective goal. Based on this, the motivational strategy of "*Gamifying by COOP*" defines the *BrainHex Socializer role* and *Brainhex Achiever role* as player roles that would be played by the participant in focus (*I*) and the participant (*You*) who gives support to the participant in focus. Playing these roles, the participants (*I* and *You*) act as *Helper* and *Accomplisher*. When the participant in focus (*I*) has the desire to accomplish the difficult collective goal, his/her individual motivational goal is the *Satisfaction of competence*, and when the participant in focus (*I*) has the desire to help others, his individual motivational goal is the *Satisfaction of relatedness*. The ontological structure also describes that as consequence of the application of the motivational strategy, it is expected changes in the motivational state for the participant in focus (*I*) from the amotivation or extrinsic motivated state to the intrinsic motivated state (*Internalization to intrinsic motivation*).

The individual motivational strategies based on gamification models currently defined in the ontology OntoGaCLeS, their player roles, their behavioral roles, and their individual motivational goals are detailed in section A.4.

3.2.4 Individual Gameplay Strategy (I-gameplay strategy)

The guidelines extracted from the literature of gamification, game design and serious games are implemented through the design of way in which the users will experience their interactions with the game-like system (FABRICATORE; LÓPEZ, 2014; NACKE; DRACHEN; GOBEL, 2010; SCHELL, 2008). Such design in gamification is frequently called as gameful design (DETERDING *et al.*, 2011; DICHEV *et al.*, 2014), and it has been formalized by the author of this thesis under the concept of *individual gameplay strategy* (*I-gameplay strategy*). In this sense, the gameplay of a gamified CL scenario is defined by the way in which the interactions between the participants and the game elements could occur. When a participant interacts with the game elements, the rules defined in the gamified CL scenario process his/her inputs causing changes in the game elements, and these modifications are communicated to the participant. These rules and changes are related to individual motivational goals that must be achieved by the participants, so that each participant has his/her own strategy to interact with the gamified CL scenario to achieve these goals. This strategy of interaction is the individual gameplay strategy, and it has been formalized by the ontological structure shown in Figure 35.

Figure 35 – Ontological structure to represent "*Individual gameplay strategy*" (at the top). At the bottom, the "*Coop. CMPT gameplay strategy*" (bottom-left), and the "*Achievement fun gameplay strategy*" (bottom-right)



Source: Elaborated by the author.

The individual gameplay strategy depends of the player roles assigned for the participants of CL scenario, the motivational strategies employed to gamify the CL scenario, and the game elements introduced in the CL scenario. Thus, the ontological structure to represent an individual gameplay strategy is defined as a rational arrangement of these elements, where:

Primary focus (P) indicates the *Player role holders* who are in the primary focus (P) of individual gameplay strategy. These player role holders are the participants who use the individual gameplay strategy (*I-gameplay strategy*) to interact with the game elements indicated in the attribute "*What to use*."

Secondary focus (S) indicates the *Player role holders* who are in the secondary focus (S) of individual gameplay strategy. These player role holders are the participants who provide support for the player role holders in the primary focus (P) through the game elements indicated in the attribute "*What to use*." It means that the individual gameplay strategy (*I-gameplay strategy*) is not necessary used by the participants in secondary focus (S) to interact with the game elements, but their interactions in the gamified CL scenario produce changes in the state of game elements indicated in the attribute "*What to use*."

S<=I-mot goal indicates the motivational strategies employed in the gamified CL scenario to motivate the player role holders who are in the primary focus (P).

P<=S-mot goal indicates the motivational strategies employed in the gamified CL scenario to motivate and engage the player role holders who are in the secondary focus (S).

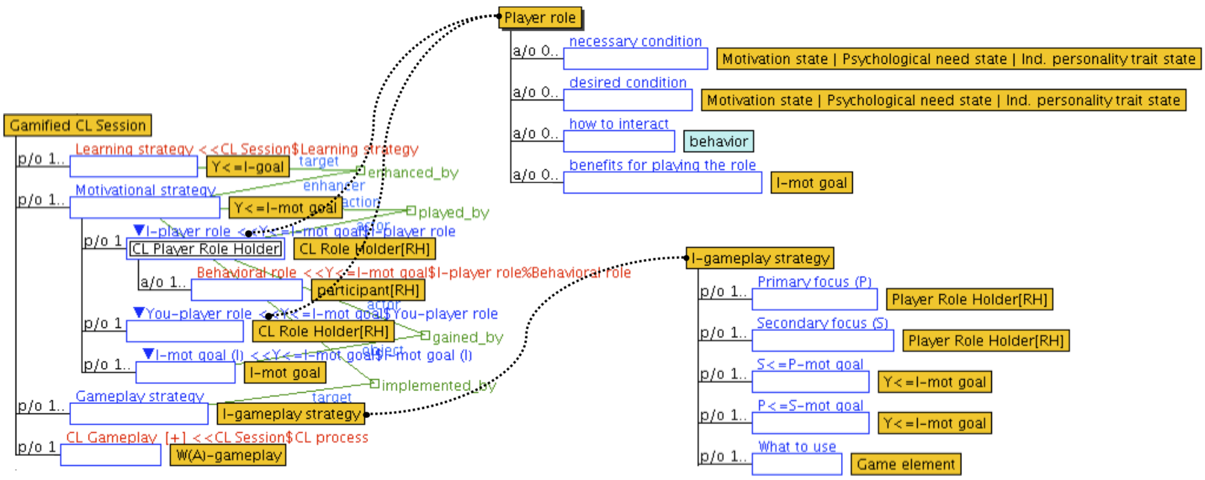
What to use indicates the game elements that are needed to carry out the individual gameplay strategy. Thus, the game elements defined in this attribute are the ones that are used to process the interactions of participants who are in the primary focus (P).

Currently, in the literature of gamification and game design, there is no one set of gameplay strategies established that could be directly formalized as individual gameplay strategies employing the ontological structure (*I-gameplay strategy*) proposed here. Therefore, the author of this thesis has inferred some individual gameplay strategies employing the guidelines of gamification and game design models. Figure 35 shows two examples of this formalization in which the guidelines described in the Yee's model (YEE, 2006b) have been used to formalize the cooperative competition gameplay strategy (*Coop. CMPT gameplay strategy*) shown at the bottom-left of figure. According to this structure, a cooperative competition gameplay strategy is beneficial for participants who are holders of Yee's Socializer role, Primary focus (P), when the motivational strategy "*Gamifying for Yee Socializer*" is applied in a CL scenario to motivate these group of participants to interact with other participants who are also holders of Yee's Socializer role, Secondary focus (S). In the attribute "*What to use*," this structure also indicates that game challenges for groups/teams, game level/progression systems for groups/teams, game point system for groups/teams, game leaderboard system with groups/teams rankings, game achievement system for groups/teams, and game badge systems are necessary to implement the cooperative competition gameplay strategy.

3.2.5 Gamified CL Scenario

A gamified CL scenario is a CL scenario in which the concepts previously presented in this section have been properly applied to gamify it. In this sense, to formally represent a gamified CL scenario in the ontology OntoGaCLeS, the ontological structures proposed in the CL ontology to represent a CL scenario (Figure 26) has been extended by adding the representation of motivational strategies (*Y<=I-mot goal*) and gameplay strategies (*I-gameplay strategy*) at the same level that the learning strategies (*Y<=I-goal*). The proper connection of these elements represents a "*Gamified CL Scenario*" by the ontological structures shown in Figure 36.

Figure 36 – Ontological structures to represent a "*Gamified CL Scenario*"



Source: Elaborated by the author.

As was explained in previous subsections, the individual motivational strategy (*Y<=I-mot goal*) describes the guidelines used to enhance the learning strategy employed by the participant in focus (*I*), and the individual gameplay strategy (*I-gameplay strategy*) describes the strategy used to implement the guidelines of individual motivational strategies. Based on these definitions, in the ontological structures to represent a gamified CL scenario (Figure 36), the connection of these elements has been represented by the two relational-concepts: "*enhanced_by*" and "*implemented_by*." The relational-concept "*enhanced_by*" indicates what individual motivational strategy (*Y<=I-mot goal*) is used to enhance a learning strategy (*Y<=I-goal*), and the relational-concept "*implemented_by*" indicates what individual gameplay strategy (*I-gameplay strategy*) is used to implement the guidelines of an individual motivational strategy (*Y<=I-mot goal*).

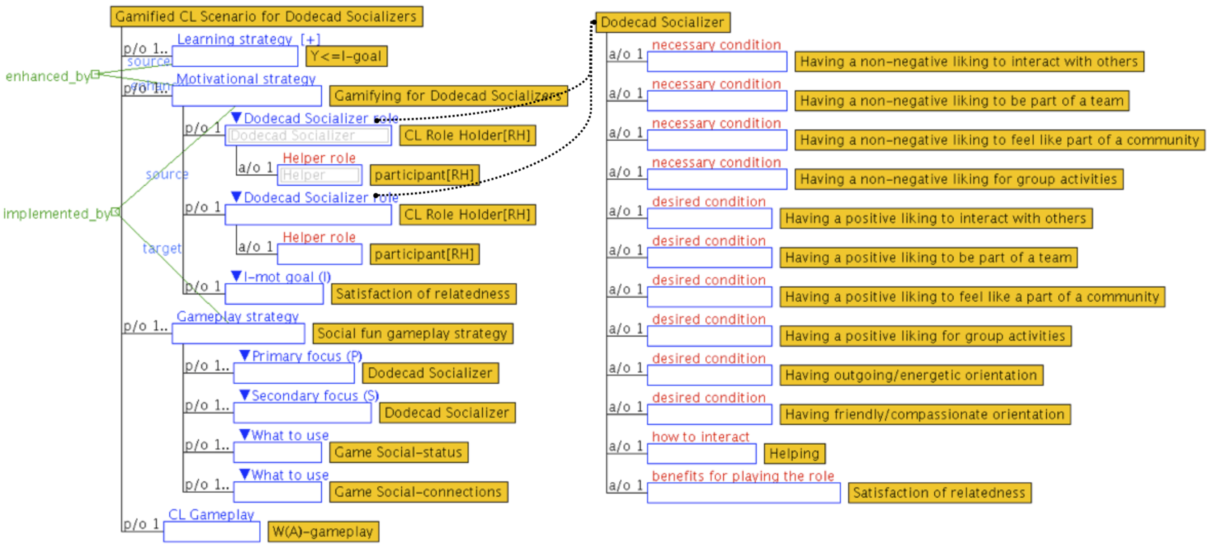
To illustrate the use of the ontological structures proposed in Figure 36, a gamified CL scenario for participant who plays the Dodecad Socializers has been formalized as shown in Figure 37, where the learning strategies (*Y<=I-goal*) of participants are *enhanced by* the individual motivational strategy "*Gamifying for Dodecad Socializer*." According to this motivational strategy:

> "... Socializers are motivated by relatedness. They want to interact with others and create social connections ... Socializers are the ones who want to interact with others. They like to be connected to others. They are interested in parts of the system that help them do this. These are the ones will evangelize your internal social networks. Most motivated by the

> social connections aspects of relatedness ... Socializer and Networkers will wish to interact with people. Neither will be after anything from people directly. In the case of a networker, their reward comes from being connected; whereas the socialiser's reward is knowing you and interacting with you ..." Marczewski (2015c).

Based on these guidelines, the individual motivational strategy "*Gamifying for Dodecad Socializer*" indicates that a participant who plays the Dodecad Socializer role (*I-player role*) interacts with other socializer (*You-player role*) acting as *Helper* to achieve the *Satisfaction of relatedness* (*I-mot goal*). In this sense, the motivational strategy is *implemented by* a *Social fun gameplay strategy* (*I-gameplay strategy*) in which, to support the communication and cooperation of participants, the game social-status and game social-connections were inferred as necessary game elements to carry out the social fun gameplay strategy. This inference pertains to the author of this thesis, and it consists in that participants who play the socializer role are interesting into help others by looking for social connections and status to satisfy his/her need of relatedness.

Figure 37 – Ontological structures to represent a "*Gamified CL Scenario for Dodecad Socializers*"



Source: Elaborated by the author.

3.3 Formalizing an Ontological Model to Personalize the Gamification in Collaborative Learning Scenarios

Through the use of ontological structures presented in the previous section, the author of this thesis expects to facilitate the systematic formalization of gamified CL scenarios based on concepts extracted from player types models and need-based theories of motivation. With this formalization, it is possible to built ontological models to personalize the gamification in CL scenario. These models consist in a set of gamified CL scenarios formally represented as the ontological structures proposed in Figure 36. The building of these structures to define an ontological model comprises the following steps: (1) to identify the player roles that can be assigned for the participants of CL scenario when they are playing a CL role, (2) to identify the restriction and elements of motivational strategies for each pair of identified player roles, and (3) to define individual gameplay strategies for the identified pairs of player roles.

In this section, following these steps, the building of an ontological model to personalize the gamification in CL scenario is detailed in this section. This model has been built to gamify CL scenarios based on the Peer-tutoring theory (ENDLSEY, 1980) in which the Dodecad player type model (MARCZEWSKI, 2017; MARCZEWSKI, 2015b) have been used as source of information to formalize this model.

Step (1): Identifying Player Roles for CL Scenarios

The identification of player roles to gamify a CL scenario is carried out by analyzing the expected behaviors to be externalized for these roles and the CL roles. Possible counterproductive behaviors indicate what player roles cannot be assigned to a participant when he/she plays the CL role. Chart 8 shows the result of this step (1) for the CL roles of "*Peer-Tutor*" and "*Peer-Tutee*" defined in CL Scenarios based on the Peer-tutoring theory. Counterproductive behaviors of player roles are avoided to not interfere with the expected behaviors of CL roles. Thus, for example, participants who are playing the CL roles of Peer-tutor and Peer-tutee cannot play the *Griefer roles* because they want to negatively affect other users.

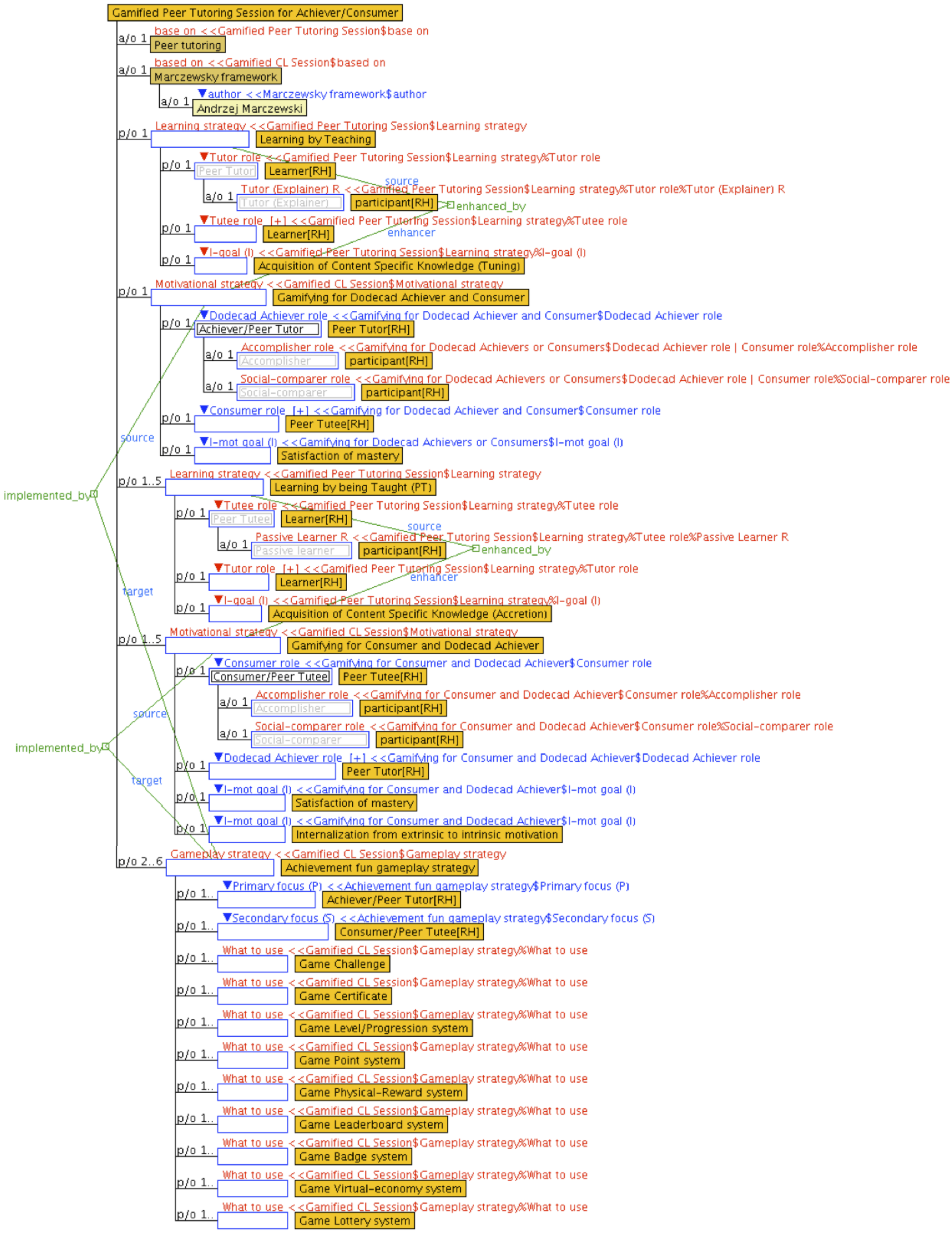
Chart 8 – Dodecad player roles that can be assigned for participants of a Peer-tutoring scenario

	Peer-Tutor (explaining)	**Peer-Tutee** (passive learning)
Achiever (accomplishing, comparing)	Yes	Yes
Free-Spirit (creating, exploring)	No (don't want to be restricted)	No (don't want to be restricted)
Socializer (helping)	Yes	Yes
Philanthropist (giving, helping, sharing)	Yes	Yes
Consumer (accomplishing, comparing)	Yes	Yes
Exploiter (creating, exploring)	No (don't want to be restricted)	No (don't want to be restricted)
Networker (helping)	Yes	Yes
Self-Seeker (giving, helping, sharing)	Yes	Yes
Destroyer (hacking)	No (hacking to ruin experience of others)	No (hacking to ruin experience of others)
Improver (hacking, exploring, fixing)	No (hacking to change the system)	No (hacking to change the system)
Influencer (commenting)	No (requiring changes in the system)	No (requiring changes in the system)
Griefer (troublemaking, defying)	No (negatively affect to others)	No (negatively affect to others)

Source: Elaborated by the author.

Peer Tutoring Scenario for Networkers, *Gamified Peer Tutoring Scenario for Philanthropists*, *Gamified Peer Tutoring Scenario for Philanthropist/Self-seeker*, *Gamified Peer Tutoring Scenario for Self-seeker/Philanthropist*, and *Gamified Peer Tutoring Scenario for Self-seekers*.

Figure 38 – Ontological structure to represent "*Gamified Peer Tutoring Scenario for Achiever/Consumer*"



Source: Elaborated by the author.

Figure 38 shows as example the formalization of *Gamified Peer Tutoring Scenario for Achiever/Consumer* in which the motivational strategy to enhance the learning strategy "*Learning by Teaching*" is "*Gamifying for Dodecad Achiever*," and the motivational strategy to enhance the learning strategy "*Learning by being Taught*" is "*Gamifiying for Consumer*." These both motivational strategies are implemented by the gameplay strategy "*Achievement fun gameplay strategy*," where the participants in the primary focus (P) are holders of *Achiever/Peer Tutor* roles, and the participants in the secondary focus (S) are holders of *Consumer/Peer Tutee* roles. As can be appreciated in the motivational strategy "*Gamifying for Dodecad Achiever and Consumer*," the potential player for the *Dodecad Achiever role* has been defined as a *Peer Tutor*, and in the motivational strategy "*Gamifying for Consumer and Dodecad Achiever*," the *Peer Tutee* has been defined as the potential player for the *Consumer role*.

3.4 Concluding Remarks

In this chapter, concepts extracted from player types models and need-based theories of motivation have been formalized in the ontology OntoGaCLeS to solve the context-dependency related to the participants' individual characteristics and traits when a CL scenario is been gamified to deal with the motivation problem causes by the scripted collaboration. The formalization of these concepts consist in ontological structures to represent individual motivational goals, player roles, motivational strategies, individual gameplay strategies, and gamified CL scenarios.

Through the use of ontological structures proposed in this chapter, it is possible the systematic building of ontology-based models to personalize gamification in CL scenarios based on player types models. This usefulness is demonstrated through an example in which information of Dodecad player type model, is employed to formalize an ontological model to personalize the gamification in Peer-tutoring scenarios. Employing the same formalization, it is possible to obtain ontological models to personalize the gamification in CL scenarios based on other player type models, such as the Yee's model (YEE, 2006b), Borges' player type model (BORGES *et al.*, 2016), and BrainHex player type (NACKE; BATEMAN; MANDRYK, 2014).

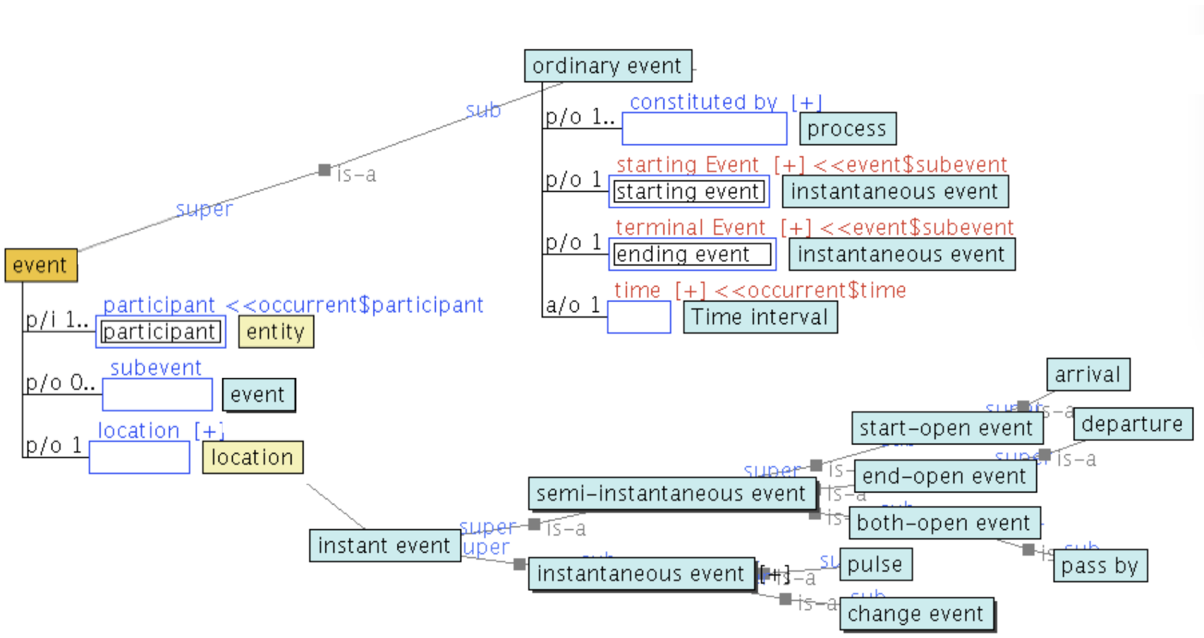
With the ontological structures proposed in this chapter, computer-based mechanisms could be built to set player roles and game element for each participant in CL sessions. These mechanisms will use the ontological structures formalized here as a knowledge-base that provide theoretical justification in an algorithm that help the users to gamify CL scenarios. Chapter 6 shows a computer-based mechanism developed by the author of this thesis as proof of concept to set player roles for students in CL activities of Moodle platform.

Figure 40 – “*is-a*” hierarchy structure of classes to represent concepts in the ontology OntoGaCLeS

Source: Elaborated by the author.

Figure 41 shows the formalization of events as ontological structures in the ontology OntoGaCLeS. As it shown in this formalization, the class event is classified in *ordinal event* and *instant event* in which the ordinal event is constituted by a process (e.g. *action*, *behavior*), the participants in the events are entities, and the ordinal event has instantaneous events as starting and ending event to delimit the chunk of processes that compose the event. Finally, the *ordinal event* is classified in *Game event* and *Non-game event* as shown in the "*is-a*" hierarchy of classes (Figure 40). The composed events in the "*is-a*" hierarchy structure of classes are defined as subtype of *event*, and they are: *I_L event*, *Gameplay event*, *Gamified Instructional event*, *Gamified Learning event*, and *Gamified I_L event*. The formalization as ontological structures of these events is detailed in the following sections.

Figure 41 – Ontological structures to represent events



Source: Elaborated by the author.

4.2 Modeling Persuasive Game Design

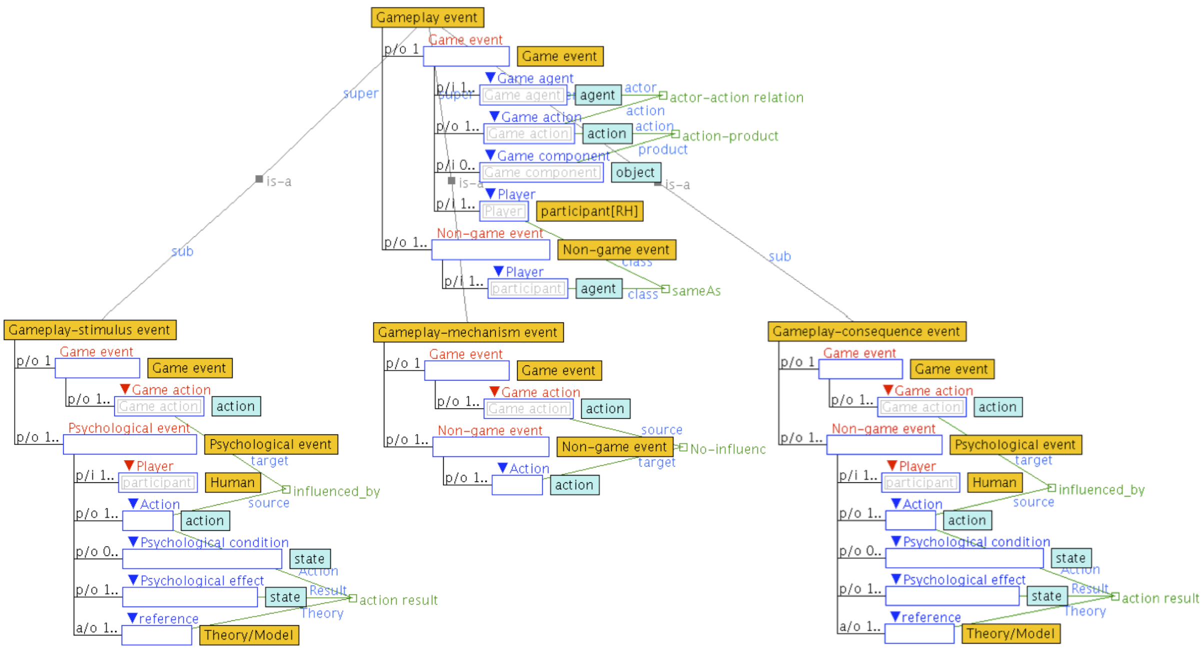
Persuasive Game Design (PGD) is defined as "*the game design for the purpose to change peoples' attitudes, intentions, motivations and/or behaviors through persuasion and social influence without using coercion and/or deception*." In this sense, to represent the PGD as ontological structures, an ontology-based formalization of the *game design* is needed because PGD is conceptualized as a game design that is embedded in persuasive design.

As was explained in the previous section, game design models are used to define the game events whereby the changes in the users' states are produced or induced in a non-game events, and these changes are explained by theories/models of motivation a human behavior. Therefore, the game design consist into establish the relation between non-game event and game event based on theoretical justification extracted from game design models and theories of motivation and human behavior. When this game design has the purpose is to change the participants' attitudes intentions, motivations, or behaviors becomes PGD, and it has been formalized in the ontology OntoGaCLeS as ontological structures to represent the *persuasive gameplay event* and the *WAY-knowledge of PGDS* detailed in subsection 4.2.1 and subsection 4.2.2. Employing the ontology-based formalization of PGD, the concept of "*Persuasive Gameplay Scenario Model*" has been proposed to represent the design rationale of how to apply PGD in non-game events. The formalization of this model as ontological structures is presented in subsection 4.2.3.

4.2.1 Persuasive Gameplay Events

The PGD is explicitly represented as the relation between game events and non-game events in the ontology OntoGaCLeS under the concept of *Gameplay event*. This concept describes, in an explicit way, what happens in the non-game world and the game world when the user is persuaded and/or social influenced to interacts with the system. Figure 42 shows the ontological structures proposed to represent persuasive gameplay events, where the *Gameplay event* (at the top of figure) represents any interaction that would occur between the participants and the game elements in the system that is being gamified. In the formalization of gameplay event, the *Game event* describes actions performed by an *agent* that becomes *Game agent*, an *action* of this agent becomes *Game action*, the *participant* who interacts with the game agent becomes *Player*, and the object produced as consequence of *Game action* becomes a *Game component*.

Figure 42 – Ontological structures to represent persuasive gameplay events. "*Gameplay event*" at the top, "*Gameplay-stimulus event*" at the bottom-left, "*Gameplay-mechanism event*" at the bottom-center, and "*Gameplay-consequence event*" at the bottom-right.

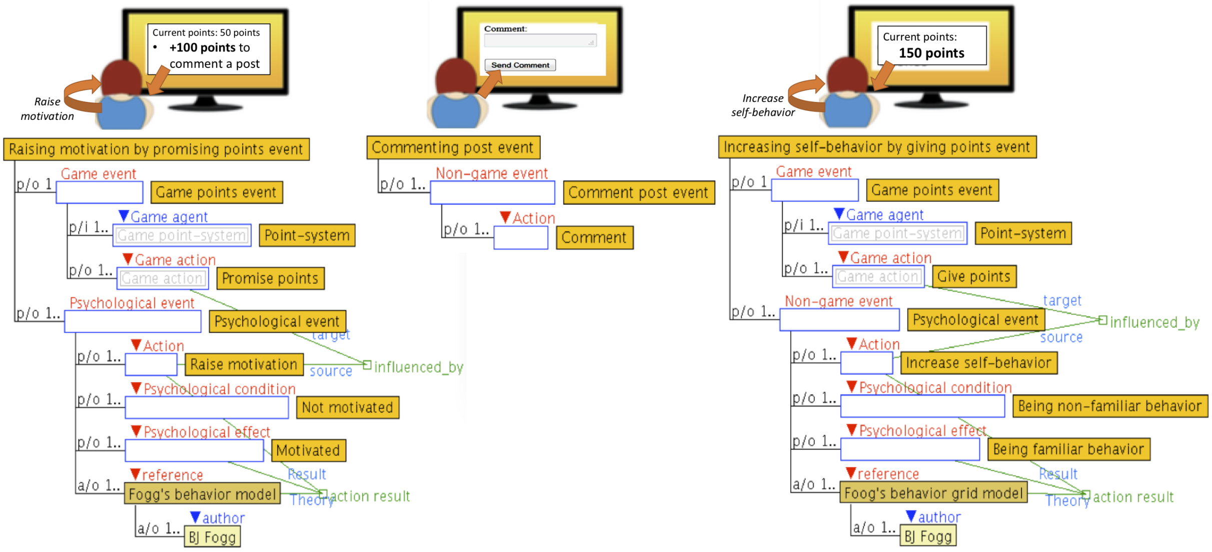


Source: Elaborated by the author.

When game events are used to lead the participants into take actions by persuasion and/or social influence, there are three types of interactions defined as persuasive game events. These events are: *Gameplay-stimulus event*, *Gameplay-mechanism event*, and *Gameplay-consequence event*. The gameplay-stimulus and gameplay-consequence events are used to represent internal psychological processes that occur by influence of a game action, whereas the gameplay-mechanism event has been formalized to represent actions that occur in the non-game world. In a *Gameplay-stimulus event*, the game actions occur before the actions being gamified, and, in a *Gameplay-consequence event*, the game actions occur after the actions being gamified. These both gameplay events are formalized as ontological structures shown at the bottom-left and bottom-right of Figure 42, where the internal psychological process associated to game actions is represented as a pair of events: *Game event* and *Psychological event*. In these formalizations, the *action* of the *Psychological event* is *influenced by* the action defined as *Game action* in the *Game event*. Concepts of *state* are used in the psychological event to represent *Psychological condition* and *Psychological effect* related to the participants' changes of attitudes, intentions, motivations and/or behaviors. These changes, in the ontological structures, are explained by theories and models of motivation and human behavior (*Theory/Model*) derived and/or related to persuasion and social influence, such as classical conditioning (GORMEZANO *et al.*, 1987), operant conditioning (SKINNER, 1953), and Fogg's behavior model (FOGG, 2009).

To illustrate the use of the ontological structures presented in Figure 42, let us formally represent the gameplay events that occur when "*a participant is persuaded to obtain points by making a comment in a post*" illustrated as a storyboard shown at the top of Figure 43. This storyboard as ontological structures is formalized at the bottom of Figure 43, where *Raising motivation by promising points event* is represented as gameplay-stimulus event, the *Comment post event* is represented as gameplay-mechanism event, and the *Increasing behavior by giving points event* is represented as gameplay-consequence event. The game action "*Promise points*" and the internal psychological process "*Raise motivation*" are represented as the game-stimulus event "*Raising motivation by promising points event*" shown at the left of figure. According to this structure, the psychological effect is being *Motivated*, and the condition to achieve this state is being *Not motivated*. This change of state is explained by the Foog's behavior model (FOGG, 2009). The game-mechanism event with the *Comment post event* as the non-game event being gamified is shown at the center of figure, and it describes the action of *Comment post* performed by the participant in a non-game system. The *Increasing behavior by giving points event* at the right of figure is a gameplay-consequence event in which the action "*Increase self-behavior*" is *influenced by* the game action "*Give points*" performed by a *Point system*. The Foog's behavior grid model explains the change described in the psychological event in which the psychological condition is *Being non-familiar behavior* and the psychological effect is *Being familiar behavior*.

Figure 43 – Example of ontological structures to represent persuasive gameplay events in which "*a participant is persuaded to obtain points by making a comment in a post*" (at the bottom). At the top, the storyboard of gameplay events involved in this example.



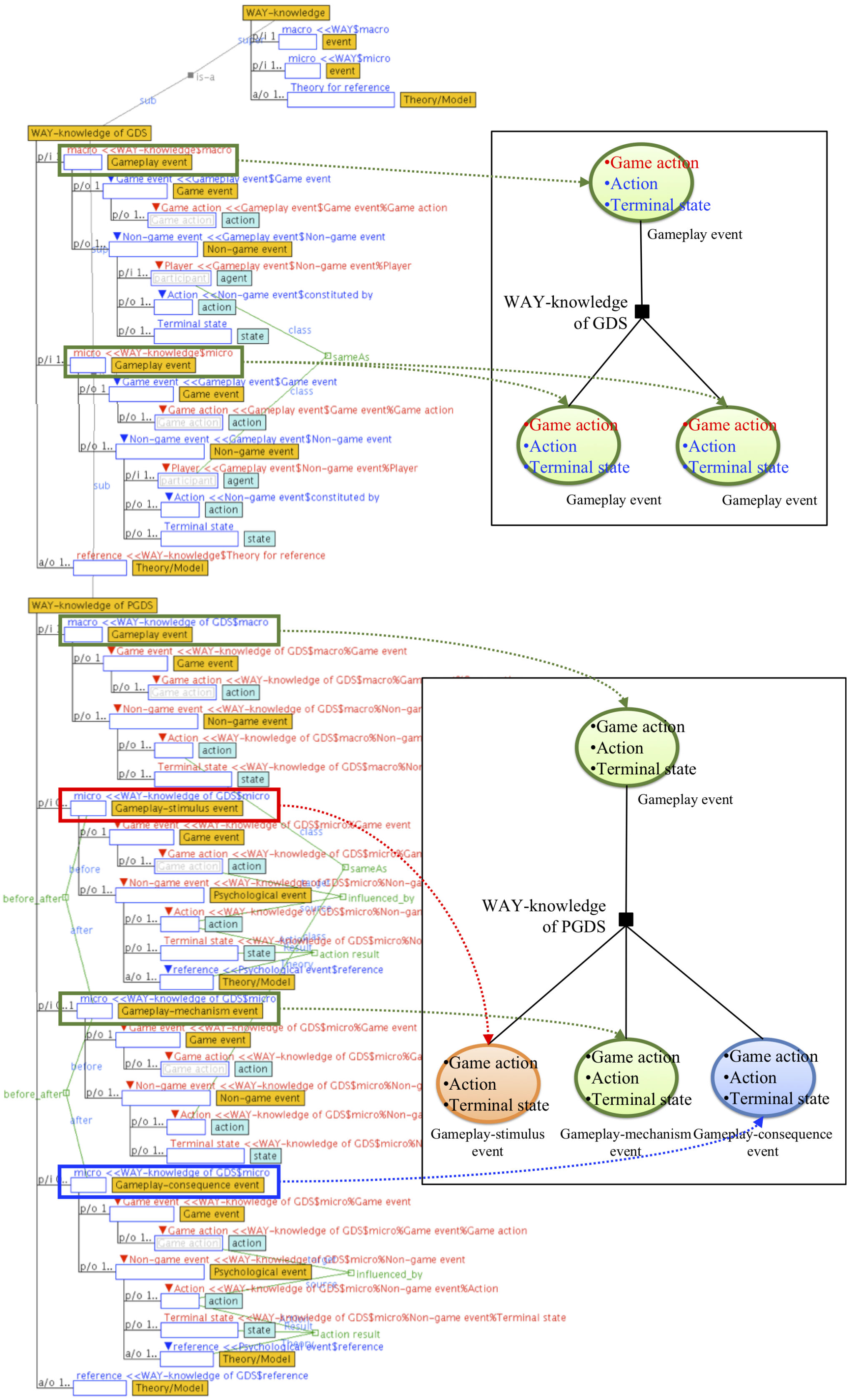
Source: Elaborated by the author.

4.2.2 *WAY-knowledge of PGDS*

WAY-knowledge of PGDS is a prescriptive description of PGD in which the relation between game events and non-game events is defined as a decomposition method of gameplay events. Thus, to describe how to achieve a specific change in the participants' attitudes and attitudes, intentions, motivations and/or behaviors, a gameplay event can be broken down into several gameplay-event sequences. The strategy of choosing a decomposition method to be applied in gameplay-event are know as *Game Design Strategy* (GDS), and when it is performed according to persuasive principles, it is known as *Persuasive Game Design Strategy* (PGDS).

PGDSs are game design strategies that are embedded in persuasive strategies, and their representation as *WAY-knowledge* constitutes a game design with the dedicate function to persuade and/or to cause social influence in the participants of non-game events. Therefore, the formalization of the knowledge involved in the PGDSs has been defined in the ontology OntoGaCLeS as a simplified version of the *WAY-structure* proposed by Kitamura and Mizoguchi (2004), Kitamura *et al.* (2004) to represent functions. The simplified version of the *WAY-structure* has been formalized as the ontological structure "*WAY-knowledge*" shown at the top of Figure 44 in which the sequence of *micro*-events represents the way to accomplish the *macro*-event. This decomposition, known as way knowledge, is theoretical grounded in a *Theory/Model* described as attribute "*Theory for reference*" in the ontological structure to represent the *WAY-knowledge*.

Figure 44 – Ontological structures to represent “*WAY-knowledge of PGDS*.”

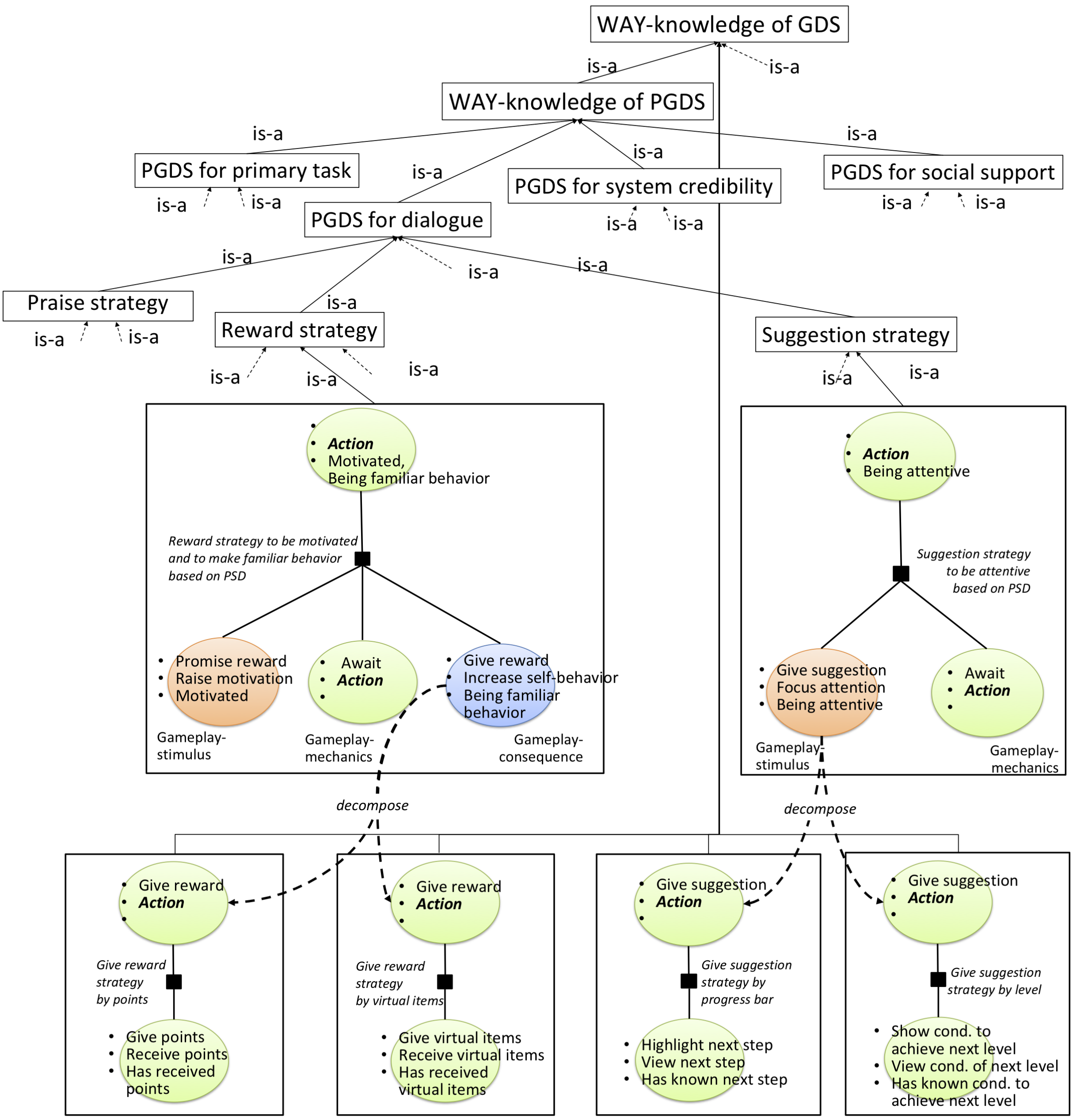


Source: Elaborated by the author.

On the left side of the Figure 44, the way knowledge about how to engender an expected terminal state in the player through his/her interaction with game elements is formalized as the ontological structure "*WAY-knowledge of GDS*." This ontological structure is a prescriptive description of the game design in which the decomposition tree shown at the right side of the figure indicates that the *Terminal state* in the *macro*-gameplay event is achieved by a sequence of *micro*-gameplay events. The way knowledge about how to achieve expected change in participants' attitudes, intentions, motivations and/or behaviors through interaction with the game elements is represented as the ontological structure "*WAY-knowledge of PGDS*" shown on the left side of the figure. This structure represents the relation between game events and non-game events as the decomposition method of a *macro*-gameplay event into a sequence of *Gameplay-stimulus events*, *Gameplay-mechanism events* and *Gameplay-consequence events* as shown in the decomposition tree shown on the right side of the figure. According to this ontological structure, the *Terminal state* in the *macro*-gameplay event represents "*what to achieve*" as the goal of decomposition method, and the terminal states in the *micro*-gameplay events represent "*how to achieve*" this goal as a sequence of sub-goals to be achieved by the *micro*-gameplay events. The goals and sub-goals as terminal states are result of actions performed by the participants in the non-game events, and when these actions are part of a internal psychological process (e.g raising motivation, increase self-behavior) influenced by game actions defined in the game events, the *micro*-gameplay event is a "*Gameplay-stimulus event*" or a "*Gameplay-consequence event*." The decomposition method is theoretically justified on *Theory/Model* that are *reference* as an *attribute-of* in the ontological structure to represent "*WAY-knowledge of PGDS*."

Based on the ontological structures to represent "*WAY-knowledge of PGDS*" (Figure 44), a WAY-knowledge base of GDSs and PGDSs has been defined in the ontology OntoGaCLeS. Part of this base is shown in Figure 45, where the PGDSs were formalized based on the Persuasive System Design (PSD) proposed by Oinas-Kukkonen and Harjumaa (2009). These PGDSs were firstly classified according to the categories of persuasive principles, and secondly, according to the expected changes in the participants' states. The decomposition tree of two PGDSs are shown in this figure in which the PGDS "*Reward strategy to be motivated and to make familiar behavior based on PSD*" has been classified as a *Reward strategy* in the *PGDS for dialogue*, and the PGDS "*Suggestion strategy to be attentive based on PSD*" has been classified as *Suggestion strategy* in the *PGDS for dialog*. The PGDS "*Reward strategy to be motivated and to make familiar behavior based on PSD*" decomposes the *macro*-gameplay event into three *micro*-gameplay events defined by the game actions: *Promise reward*, *Await*, and *Give reward*. During the gameplay-stimulus event defined by the game action "*Promise reward*," the internal psychological process is *Raise motivation* to achieve the *Terminal state* "being *Motivated*." For the gameplay-consequence event defined by the game action "*Give reward*," the internal psychological process is *Increase self-behavior* to achieve the *Terminal state* "*Being familiar behavior*." The decomposition tree of the PGDS "*Suggestion strategy to be attentive based on PSD*" indicates that, to achieve the *Terminal state* of *Being attentive*, it is necessary to follow the sequence of two *micro*-gameplay events defined by the game actions “*Give suggestion*” and “*Await*.” The internal psychological process “*Focus attention*” in the gameplay-stimulus even is influenced by the game action “*Give suggestion*” achieving the *Terminal state* “*Being attentive*.”

Figure 45 – A portion of the WAY-knowledge base of game design strategies and persuasive game design strategies defined in the ontology OntoGaCLeS



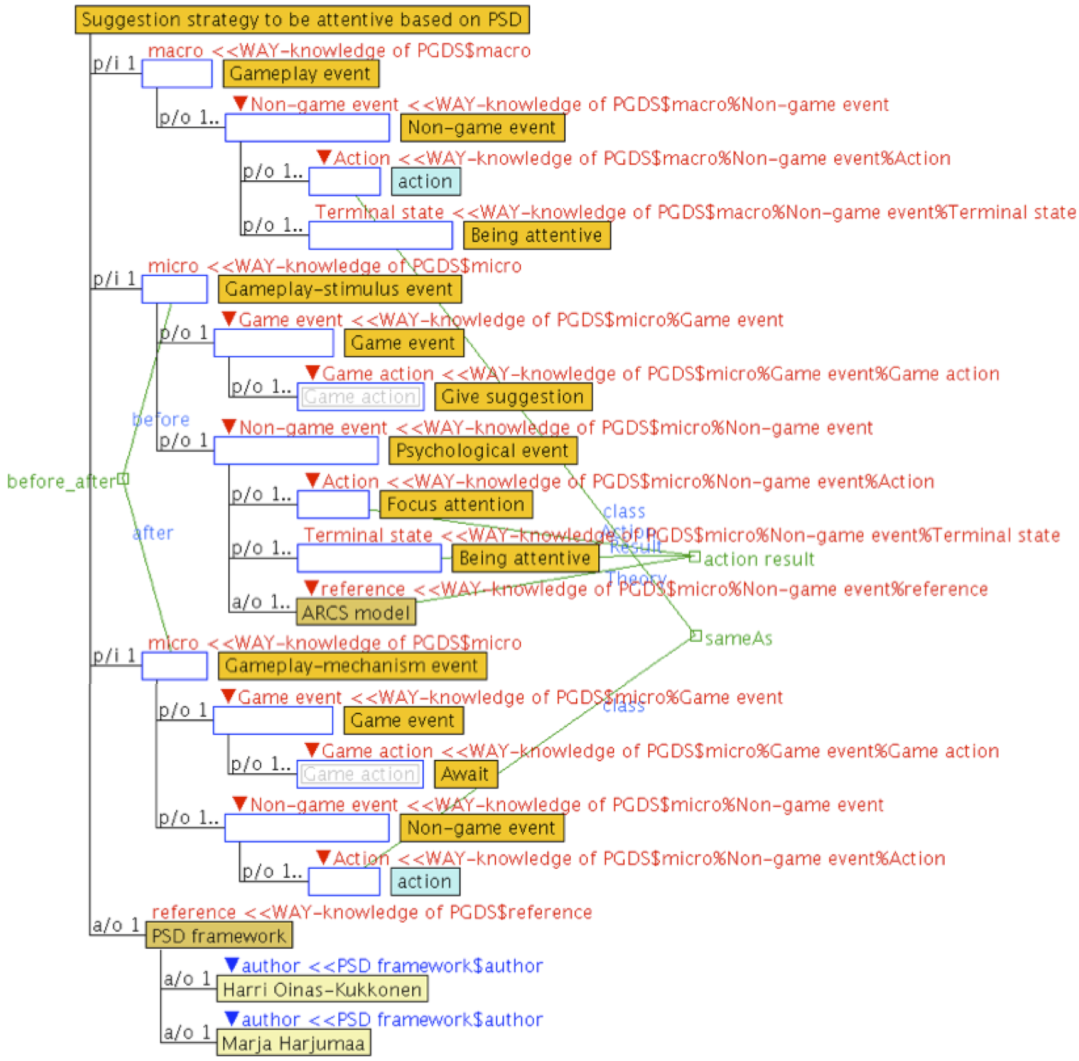
Source: Elaborated by the author.

Figure 45 also shows the decomposition tree of four GDSs that has been formalized based on the information extracted from the Model-driven persuasive game proposed by Orji (2014). The former two, known as “*Give reward strategy by points*” and “*Give reward strategy by virtual items*,” are GDSs in which the game actions “*Give points*” and “*Give virtual items*” cause the *Terminal state* “*Has received points*” and “*Has received virtual items*” by the actions

"*Receive points*" and "*Receive virtual item*." The latter two GDSs are "*Give suggestion strategy by progress bar*" and "*Give suggestion strategy by level*" to achieve the *Terminal state* "*Has known next step*" and "*Has known cond. to achieve next level*" by the actions "*View next step*" and "*View cond. of next level*."

The ontological structure to represent the PGDS "*Reward strategy to be motivated and to make familiar behavior based on PSD*" is shown in Figure 46, where the *Terminal state* as goal of the decomposition tree is defined as *Being attentive* in the *macro*-gameplay event. The sequence of *micro*-gameplay events defined by this PGDS is defined as a gameplay-stimulus event with the game action "*Give suggestion*," and a gameplay-mechanism event with the game action "*Await*." The terminal state in the gameplay-consequence event is *Being attentive* achieved by the internal psychological process "*Focus attention*" *influenced by* the game action "*Give suggestion*." This psychological effect has theoretical justification in the ARCS model (KELLER, 1987) indicated in the attribute of *reference* in the *Psychological event* of the *Gameplay-stimulus event*.

Figure 46 – Ontological structure to represent the "*Suggestion strategy to be attentive based on PSD*"

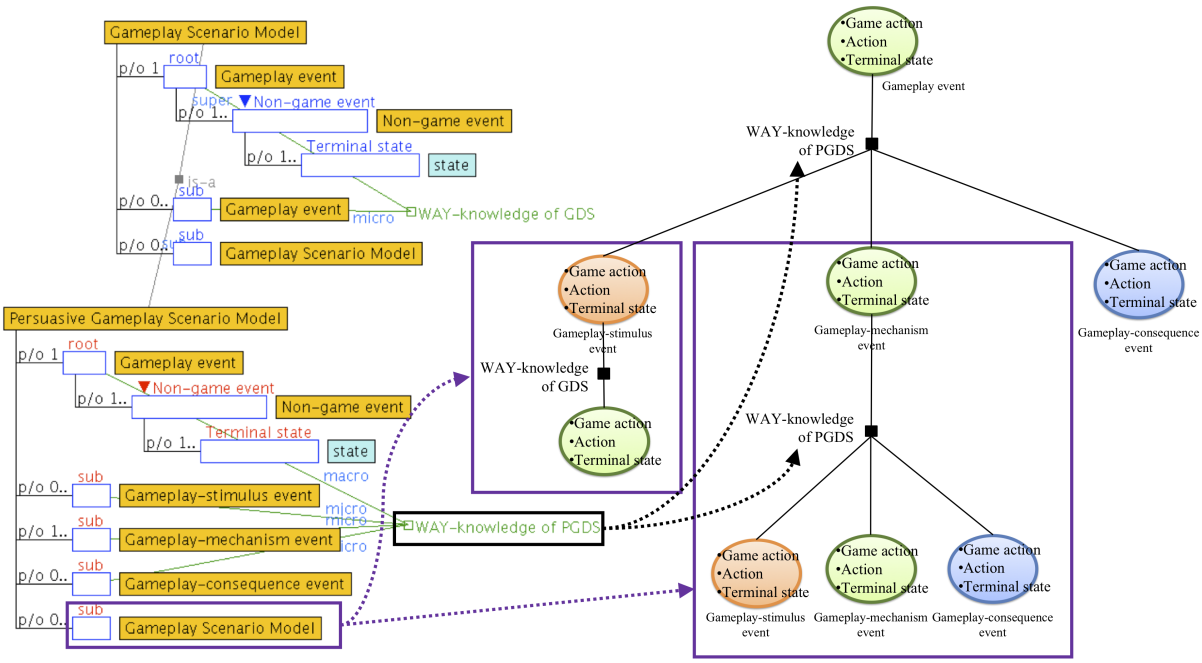


Source: Elaborated by the author.

4.2.3 Persuasive Gameplay Scenario Model

"*Persuasive Gameplay Scenario Model*" is an abstract structure to indicate the design rationale involved in the application of PGD in non-game events. This design rationale indicates the changes in the participants' attitudes, intentions, motivations and/or behaviors, and how these changes are achieved by a sequence of gameplay-events. The persuasive gameplay scenario model is constructed by applying the PGDSs into non-game events in a phased manner obtaining a sequence of gameplay-stimulus, gameplay-mechanisms and game-consequence events. The determination of when to stop the application of PGDSs is arbitrary for the model authors, and lies outside the scope of the modeling. Figure 47 shows the ontological structures proposed in the ontology OntoGaCLeS to represent a persuasive gameplay scenario model. In the ontological structure "*Gameplay Scenario Model*," the *WAY-knowledge of GDS* is represented as a link between two gameplay events playing the roles of *root* and *sub* to describe the *macro*-gameplay event and the sequence of *micro*-gameplay events resulting of the decomposition method. In the ontological structure "*Persuasive Gameplay Scenario Model*," the *WAY-knowledge of PGDS* is represented as a link between a *macro*-gameplay event playing the role of *root*, and four *micro*-gameplay events playing the role of *sub*. In both ontological structures, the concept of *Gameplay Scenario Model* plays the role of *sub* to represent the recursive application of PGDSs and GDSs in the modeling of design rationale to gamify a non-game event.

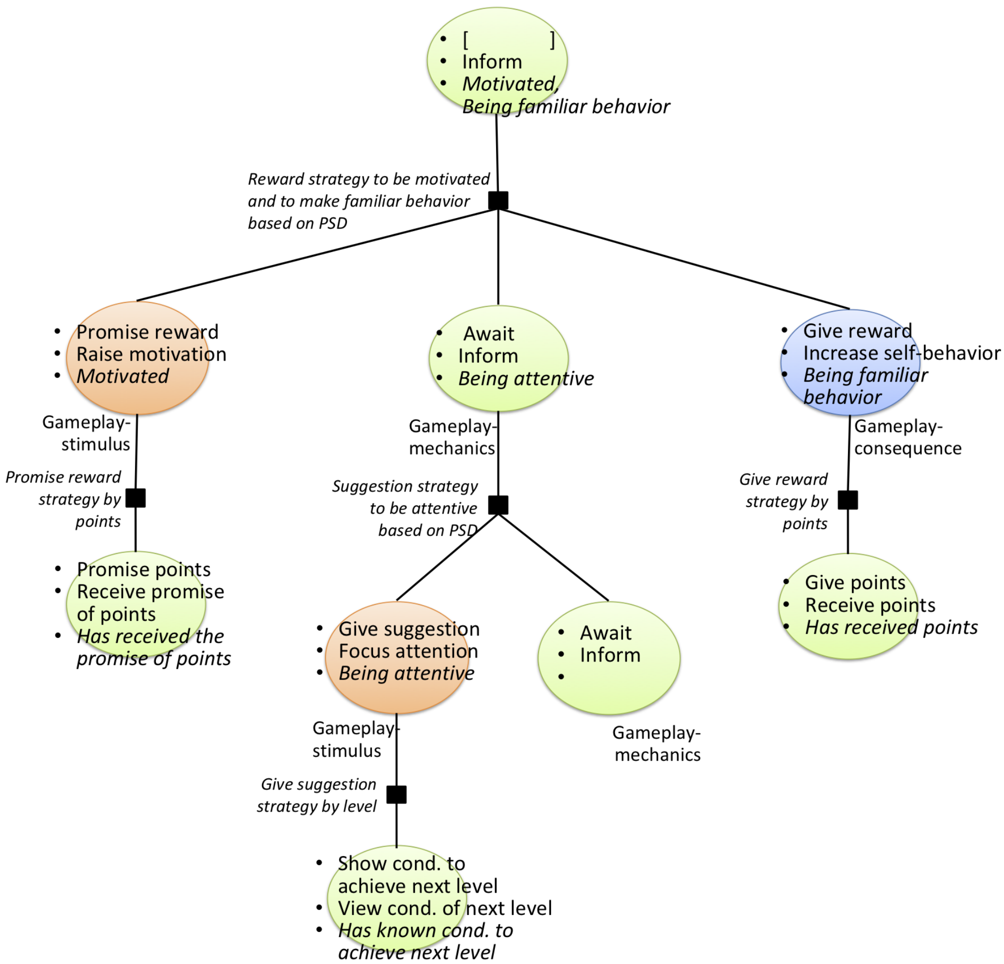
Figure 47 – Ontological structures to represent a "*Persuasive Gameplay Scenario Model*"



Source: Elaborated by the author.

An example of persuasive gameplay scenario model is shown in Figure 48. This model represents the design rationale to gamify the instructional event "*Giving information*" obtained by the application of two PGDSs and three GDSs. The PGDS "*Reward strategy to be motivated* *and to make familiar behavior based on PDS*" has been applied to achieve the *Terminal state* of *Motivated* and *Being familiar behavior*, and the PGDS "*Suggestion strategy to be attentive based on PSD*" has been applied to achieve the *Terminal state* of *Being attentive*. The GDSs "*Promise reward strategy by points*," "*Give suggestion strategy by level*," and "*Give reward strategy by points*" have been applied to accomplish the game actions "*Promise reward*," "*Give suggestion*," and "*Give reward*" achieving the terminal states of "*Has received the promise points*," "*Has known cond. to achieve next level*," and "*Has received points*."

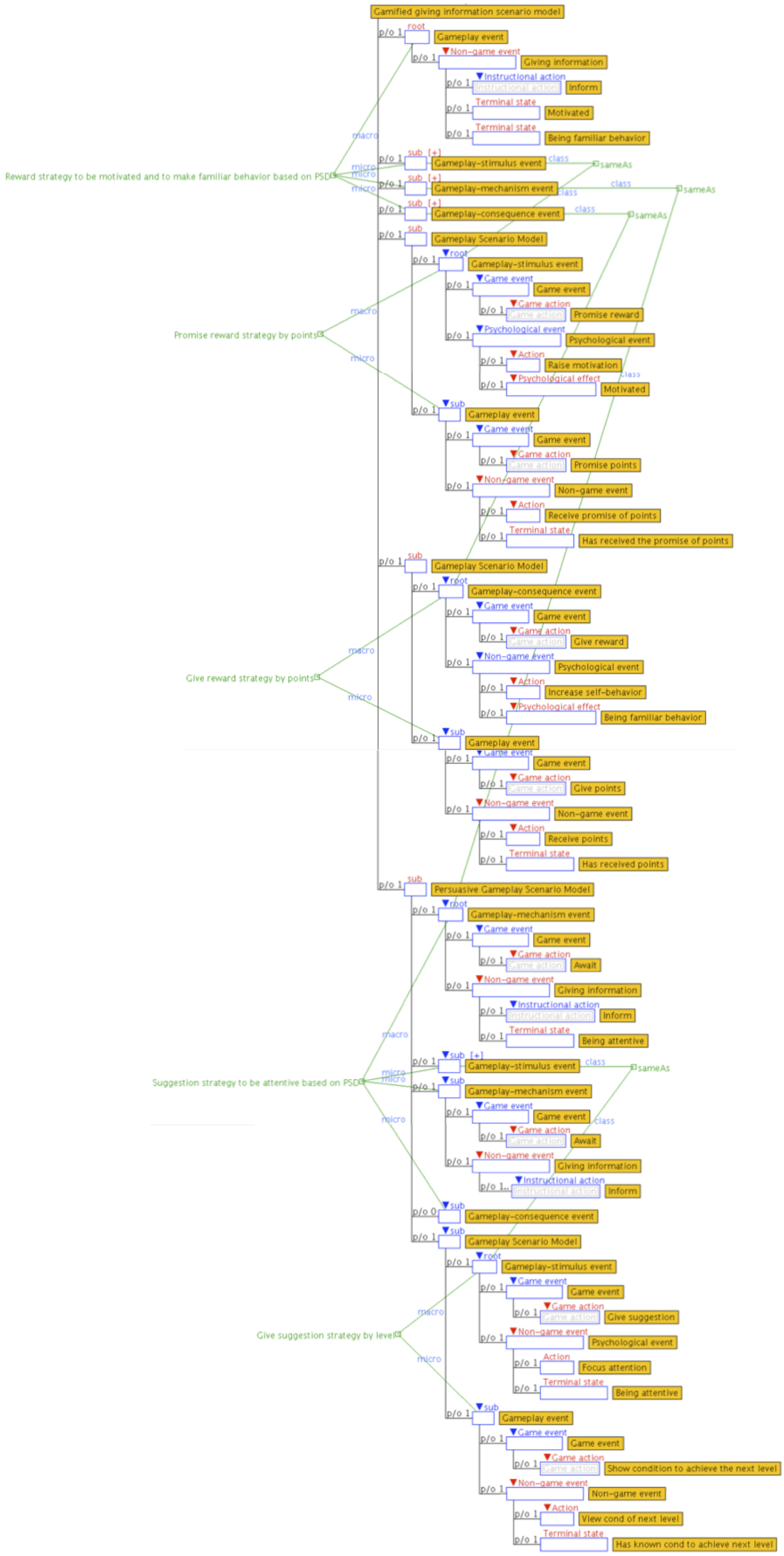
Figure 48 – Example of persuasive gameplay scenario model for the gamification of *Giving information*



Source: Elaborated by the author.

Figure 49 presents the ontological structure formalized to represent the persuasive gameplay scenario model shown in Figure 48. According to this structure, the PGDS "*Reward strategy to be motivated and to make familiar behavior based on PDS*" is represented as a link for a *Gameplay event* and three *micro*-gameplay events defined as a *Gameplay-stimulus event*, a *Gameplay-mechanism event*, and a *Gameplay-consequence event*. In the *macro*-gameplay event, the goals to be achieved by this PGDS are "*Motivated*" and "*Being familiar behavior*" defined as *Terminal state* in the *Non-game event* played by the instructional event "*Giving information*." The GDS "*Promise reward strategy by points*" is represented as a link between the *macro*- and *micro*-gameplay events defined by the game actions "*Promise reward*" and "*Promise points*," respectively. The *Psycological effect* as terminal state for the action "*Raise motivation*" in the *Gameplay-stimulus event* defined as *macro*-gameplay event is *Motivated*, and the *Terminal state* for the action "*Receive promise of points*" defined in the *micro*-gameplay event is *Has received the promise of points*. The GDS "*Give reward strategy by points*" is represented as a link between the *macro*- and *micro*-gameplay events defined by the game actions "*Give reward*" and "*Give points*," respectively. The *Psycological effect* as terminal state for the action "*Increase self-behavior*" in the *Gameplay-consequence event* defined as *macro*-gameplay event is *Being familiar behavior*, and the *Terminal state* for the action "*Receive points*" defined in the *micro*-gameplay event is *Has received points*. The *Gameplay-mechanism event* defined by the non-game event "*Giving information*" is decomposed by the PGDS "*Suggestion strategy to be attentive based on PSD*" into a *Gameplay-stimulus event* and a *Gameplay-mechanism event* to achieve the *Terminal state* of *Being attentive*. The *Gameplay-stimulus event* defined by the game action "*Give suggestion*" causes the *Psychological effect* of *Being attentive* by the psychological process "*Focus attention*." This goal is accomplished by the GDS "*Give suggestion strategy by level*" in which the game action "*Show cond. to achieve the next level*" cause the action "*View cond. of next level*" to achieve the *Terminal state* of *Has known cond. to achieve next level*.

Figure 49 – Example of ontological structure to represent the gamification of *Giving information*



Source: Elaborated by the author.

4.3 Modeling of Collaborative Learning Gameplay Based on Persuasive Game Design

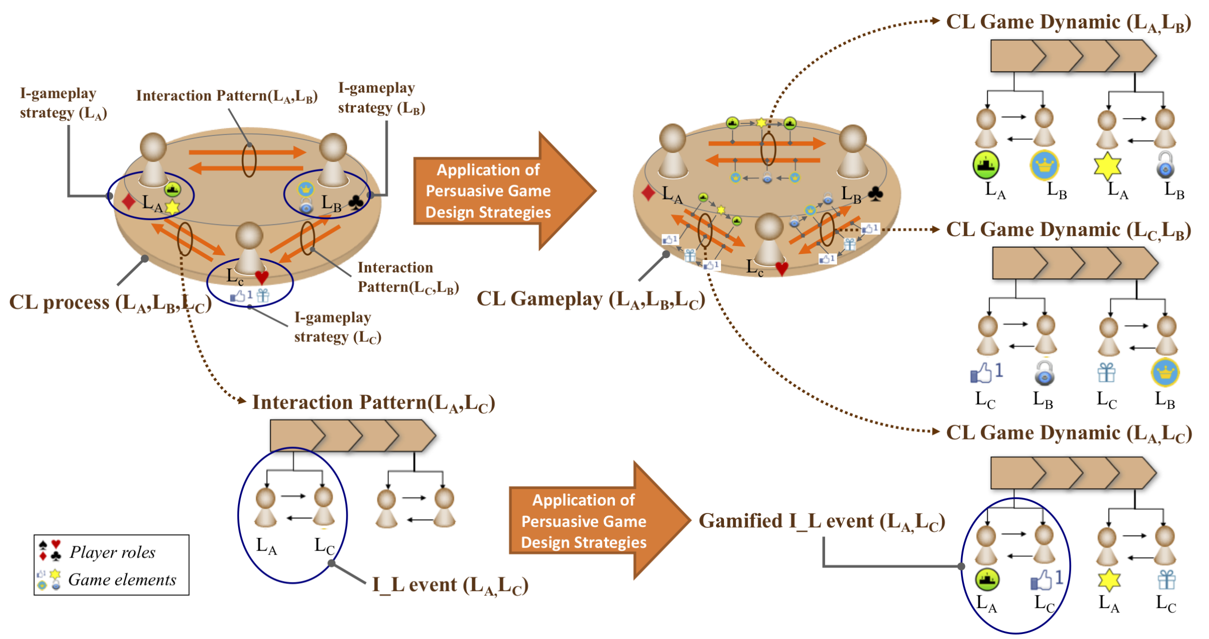
Having the ontological structures to represent Persuasive Game Design Strategies (PGDSs) and the rational design about how to successively apply them, we can procedure to link the design of CL process and the PGD for dealing with the motivation problem caused by the scripted collaboration. This link was established by the modeling of CL gameplay based on PGD. The concepts, terms and relations defined in this modeling are shown in Figure 50, where:

Gamified I_L event represents the influential I_L event in which a set of PGDSs has been applied to persuade the participants who play the instructor and learner roles to interact between them performing the instructional and learning actions defined in an I_L event.

CL Game Dynamic describes the run-time behavior of game elements acting to persuade the participants to follow the interactions defined by the sequencing mechanism of a CSCL script. This behavior is defined by the PGDSs applied to interaction patterns.

CL Gameplay is the set of CL Game dynamics defined in a gamified CL scenario to describe the whole CL process in a gamified CL scenario.

Figure 50 – Concepts, terms and relations in the modeling of CL gameplay based on PGD



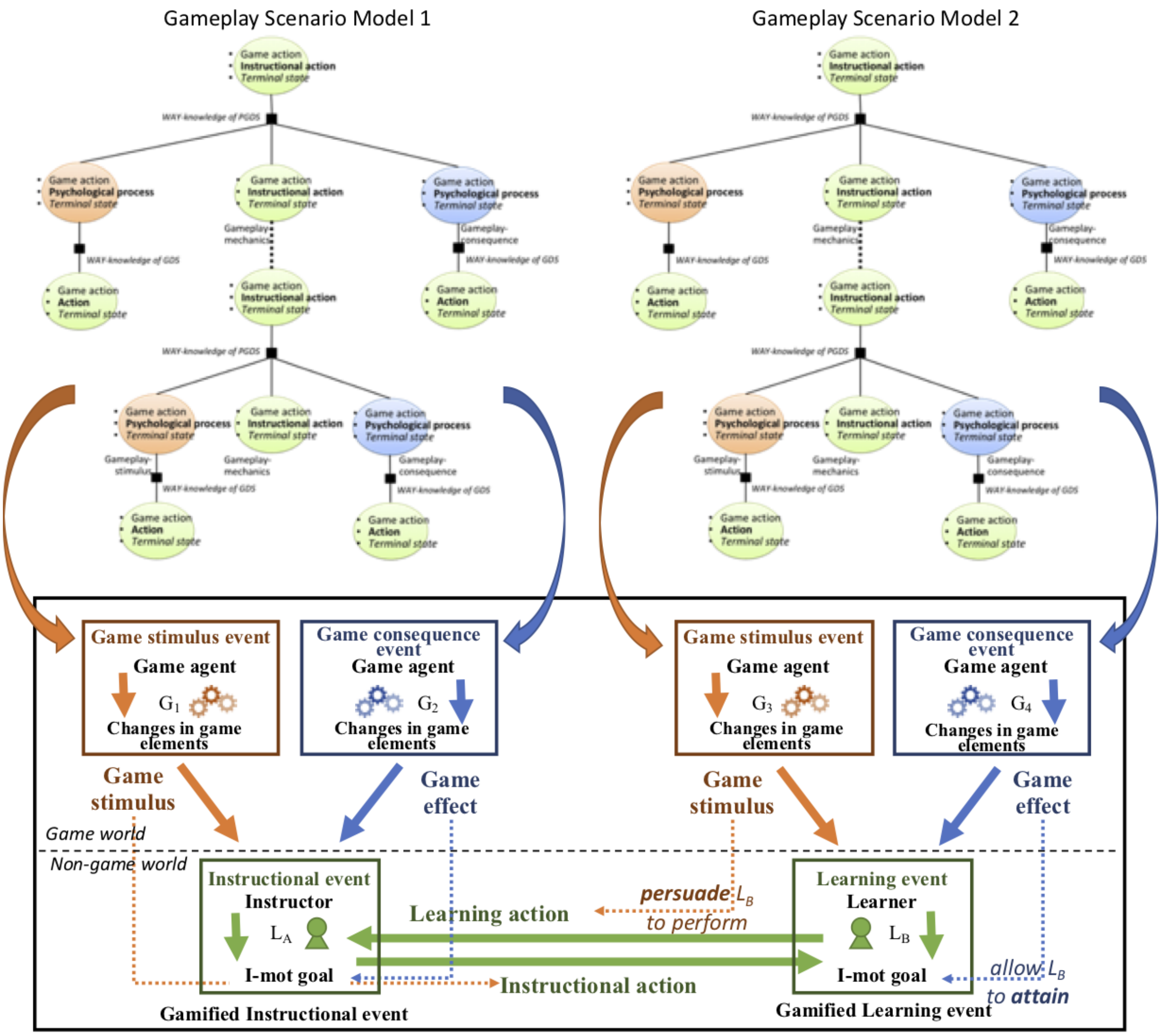
Source: Elaborated by the author.

In the following subsections, the formalization of concepts, terms and relations briefly introduced here are detailed.

4.3.1 Gamified I_L Event

In the ontology OntoGaCLeS, the interaction defined by the sequencing mechanism of a CSCL script is represented by two parts: an *Instructional event*, and a *Learning event*. Thus, in a gamified CL scenario, as shown in Figure 51, the *Gamified I_L event* has been formalized an interaction composed by the pairs of events: *Gamified instructional event*, and *Gamified learning event*. These both events are result of applying PGDSs in the instructional and learning events as illustrated in the figure in which the *Gameplay Scenario Model 1* corresponds to the instructional event, and the *Gameplay Scenario Model 2* corresponds to the learning event.

Figure 51 – Elements in a gamified I_L event

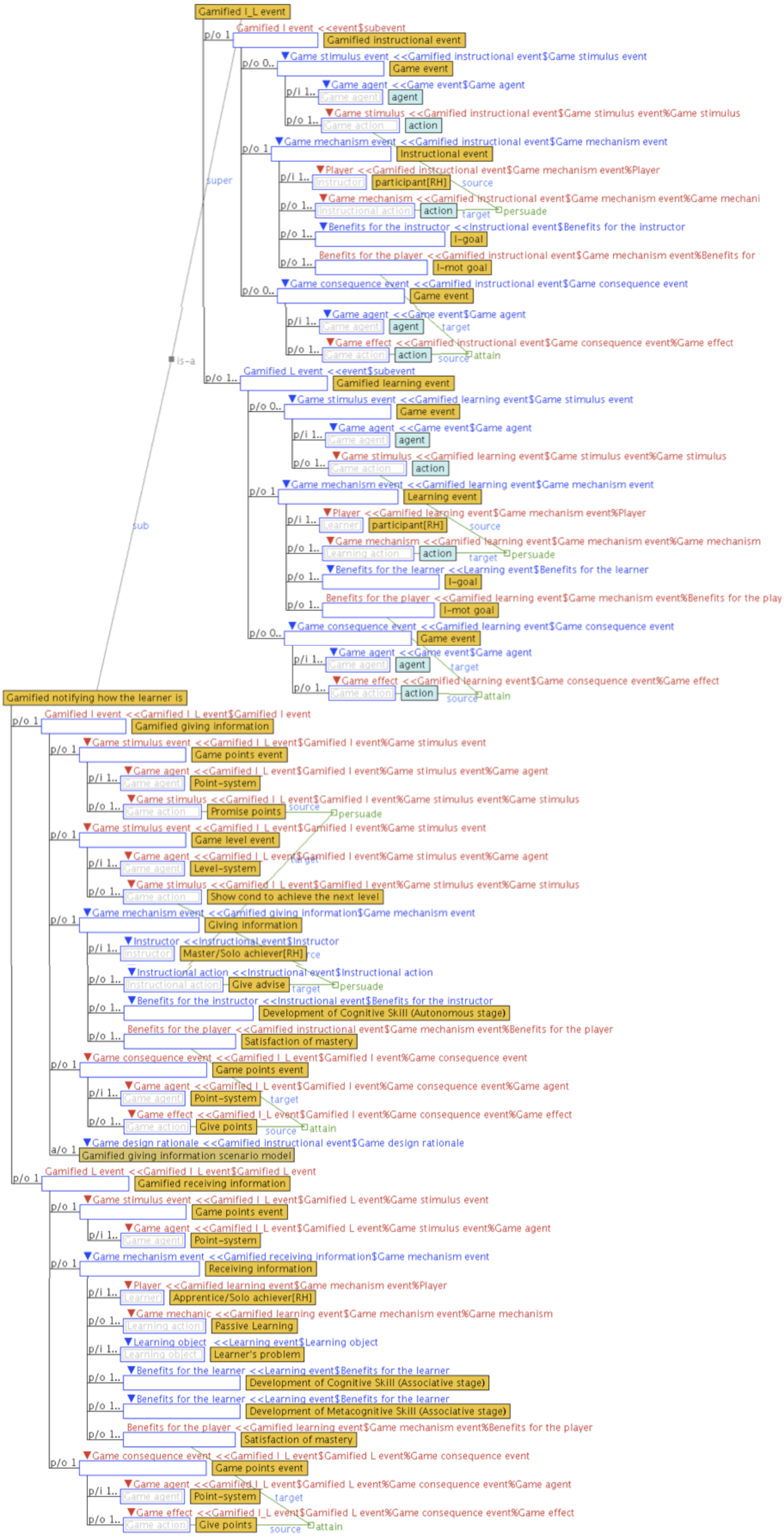


Source: Elaborated by the author.

The gameplay scenarios in a gamified I_L event describe the design rationales whereby the instructional and learning events are gamified to influence the instructor and learner role holders to perform the action indicated by the sequencing mechanism of CSCL script. Such influence is caused by game actions that occur before and after the instructional and learning actions defined in the instructional and learning events. As shown in Figure 51, when these game actions are derived from gameplay-stimulus events occurring before the instructional and learning actions, they become *game stimulus*; and when these game actions are derived from gameplay-consequence events occurring after the instructional and learning actions, they become *game effects*. The game stimulus, the game agents (G_1 and G_3) performing these stimulus, and the changes in game elements caused by the game stimulus are formalized as game stimulus events. The game effects, the game agents (G_2 and G_4) performing these effects, and the changes in game elements caused by the game effects are formalized as game consequence events. In these sense, the game actions as game stimulus carried out by the game agents (G_1 and G_3) *persuade* the instructor (L_A) and learner (L_B) to perform the instructional and learning actions indicated in the instructional and learning events. The game actions carried out by the game agents (G_2 and G_4) are game effects that allow to the instructor (L_A) and (L_B) to *attain* individual motivational goals (*I-mot goal*). These individual motivational goals represent the expected changes in the motivational stage of participants (L_A and L_B) to interact between them.

The ontological structure proposed in the ontology OntoGaCLeS to represent a "*Gamified I_L event*" is shown at the top of Figure 52. According to this structure, the role of *Gamified I event* is played by a *Gamified instructional event*, and the role of *Gamified L event* is played by a *Gamified learning event*. The *Gamified instructional event* is composed by: a *Game stimulus event* played by a *Game event*, a *Game consequence event* played by a *Game event*, and a *Game mechanism event* played by an *Instructional event*. The *Gamified learning event* is composed by: a *Game stimulus event* played by a *Game event*, a *Game consequence event* played by a *Game event*, and a *Game mechanism event* played by a *Learning event*. The instructional and learning events become game mechanism events because, when these events are gamified by the application of PGDSs, the instructional and learning actions are game mechanisms invoked by the instructor and learner to push forward through the game elements, and thus, to *attain* individual motivational goals (*I-mot goal*). These individual motivational goals are represented in the ontological structure as *Benefits for the player* that can be achieved by the instructor and learner by performing the actions indicated in the instructional and learning events. The link "*persuade*" in the *Gamified I event* and *Gamified L event* indicates the relation concept between game stimulus and instructional/learning actions. This link represents the instructional and learning actions influenced by persuasion and/or social influence. The link "*attain*" in these both gamified events (*Gamified I event* and *Gamified L event*) indicates the relation concept between game effects and individual motivational goals (*I-mot goal*) in which the game effects are actions that allow the learner and instructor to accomplish the individual motivation goals.

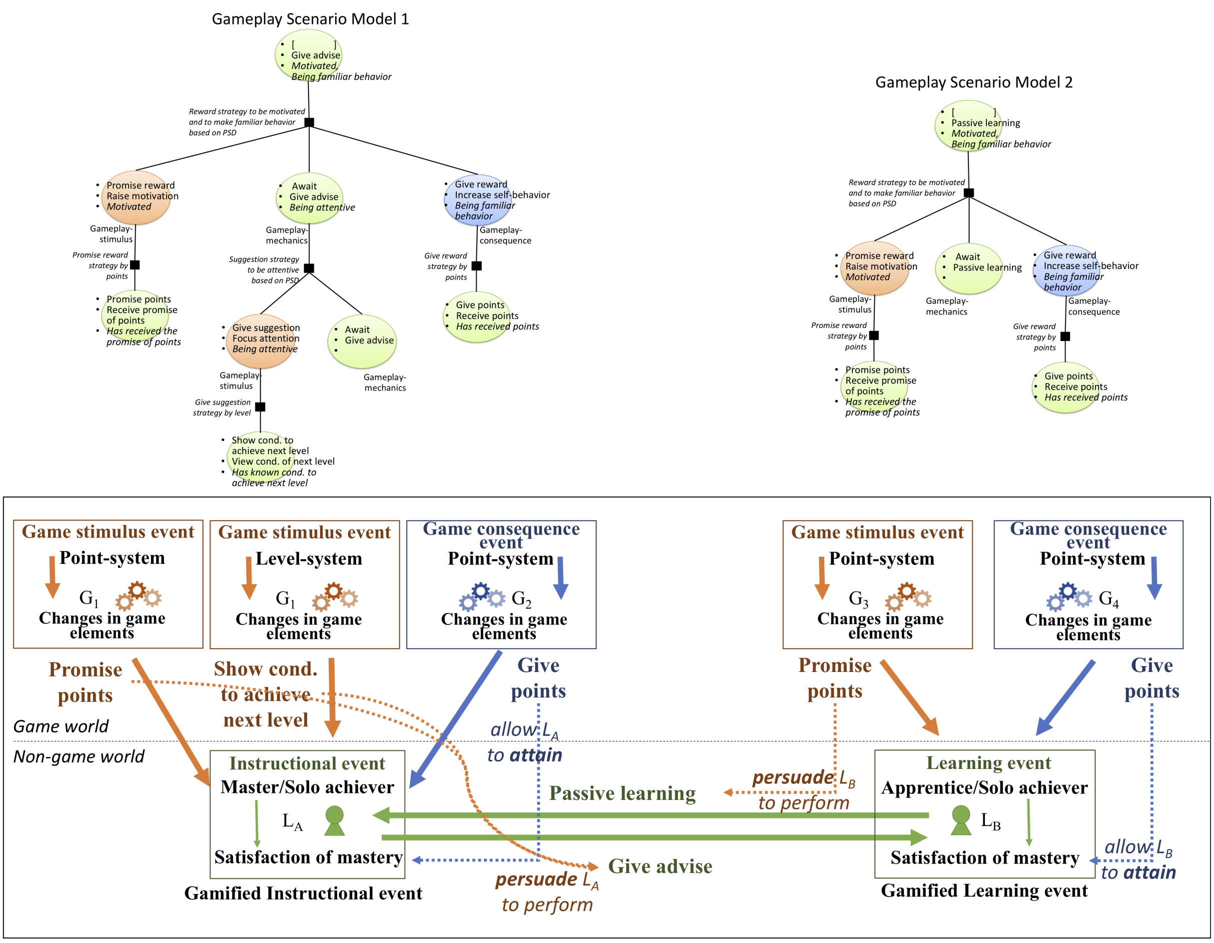
Figure 52 – Ontological structure to represent a "*Gamified I_L event*" (at the top). At the bottom, an example of Gamified I_L event "*Gamified Notify how the learner is*" as ontological structure.



Source: Elaborated by the author.

At the bottom of Figure 52, there is shown the ontological structure to represent a Gamified I_L event "*Gamified Notify how the learner is*" illustrated in Figure 53. This ontological structure is result of applying the PGDSs and GDSs of *Gameplay Scenario Model 1* and *Gameplay Scenario Model 2* for the Instructional event "*Giving information*" and the Learning event "*Receiving information*." The *Gameplay Scenario Model 1* is indicated as the attribute "*Game design rationale*" in the *Gamified giving information*. According to this game design rationale, a game points event becomes game stimulus event when the game action "*Promise points*" as game stimulus carried out by the *Point-system* persuades the *Master/Solo achiever role holder* as instructor to perform the instructional action "*Give advise*" that becomes game mechanism. A game level event becomes game stimulus event when the game action "*Show cond. to achieve the next level*" as game stimulus carried out by the *Level-system* persuades the *Master/Solo achiever role holder* as instructor to perform the instructional action "*Give advise*" that becomes game mechanism. The game points event becomes game consequence event when the game action "*Give points*" performed by the *Point-system* allows the *Master/Solo achiever role holder* as instructor to *attain* the *Satisfaction of mastery* defined as *Benefits for the player*.

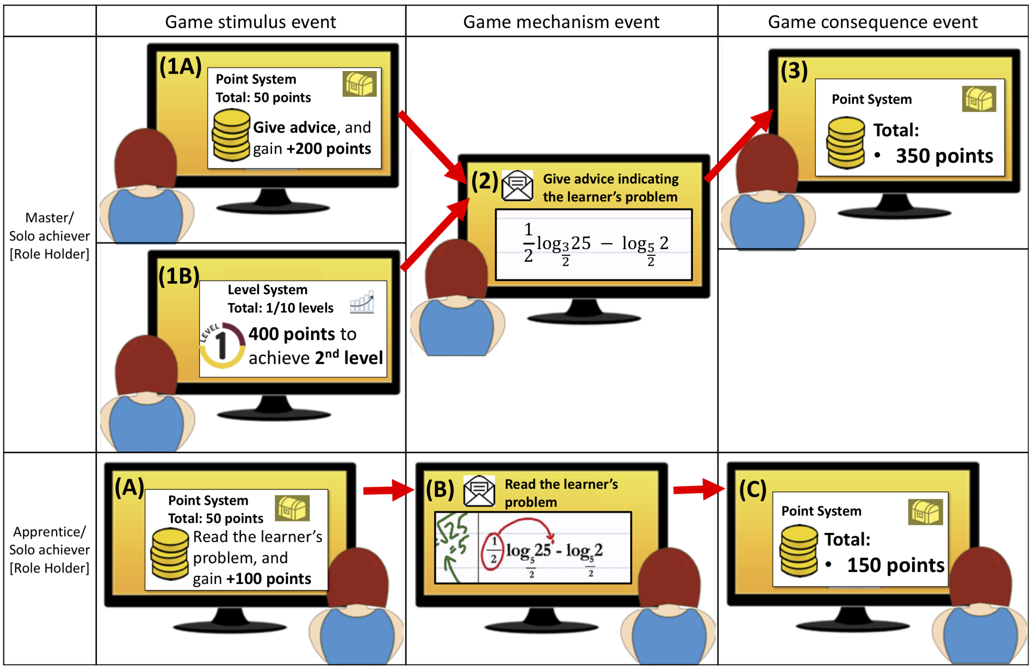
Figure 53 – Elements in an example of gamified I_L event "*Gamified Notify how the learner is*."



Source: Elaborated by the author.

Having the representation of gamified I_L events using ontological structures, there is the possibility to use the information contained in these structures to setting up the game elements introduced in the CL scenario being gamified. Because the information is explicitly and formally represented in the ontological structures, the designer can use this information to establish the interactions between the game elements and participants in a CL scenario. Thus, for the gamified I_L event "*Gamfied Notify how the learner is*" shown as an ontological structure at the bottom of Figure 52 and with the elements illustrated in Figure 53, the interactions between participants and game elements can be established in the CL scenario according to the storyboard shown in Figure 54. In this sense, the game actions "*Promise points*" and "*Show cond. to achieve next level*" indicated in the ontological structure as game stimulus are defined as the messages "*Give advice, and gain +200 points*" and "*400 points to achieve 2nd level*" to be given by a point-system and a level-system as shown in the screens (1A) and (1B). These both message must be displayed in the system before the instructional action "*Give advice*" defined in the ontological structure as a game mechanism. Such instructional action is defined in the system as a message "*Give advice indicating the learner's problem*" and an interactive form to be filled by the *Master/Solo achiever role holders*. The game action "*Give points*" formalized as a game consequence in the ontological structure is setting up as the assignment of points and the message to be given to the *Master/Solo achiever role holders* by the point-system as shown in the screen (3).

Figure 54 – Storyboard for the interactions between game elements and participants defined according to the example of gamified I_L event "*Gamified Notify how the learner is*."



Source: Elaborated by the author.

The configuration of game elements in the system for the *Apprentice/Solo achiever role holders* is established as shown in the screens (A), (B) and (C) of Figure 54. This configuration is established according to the information provided by the ontological structure shown at the bottom of Figure 52. In this sense, the game action "*Promise points*" as game stimulus is setting up as the message "*Read the learner's problem and gain +100 points*" to be given by the point-system (Screen (A)), and the game action "*Give points*" as game consequence is defined as the assignment of points and the message to be given by the point-system (Screen (C)).

The task of setting up the game actions to be performed by the game agents can be supported by an intelligent system that is able to reason on ontologies. Thus, the designer just needs to have a clear idea of individual motivational goals (*I-mot goal*) to be achieved by the instructor and learner in the gamified I_L event. These individual motivational goals represented as the expected *Benefits for the players* in the ontological structures provide information to the intelligent system to find the game action that support the achievement of these benefits. These game actions are actions indicated as game stimulus and game consequences in the gamified I_L event, and they can be found by the intelligent system when it has the information of player roles and individual motivational goals assigned for the instructor and learner in a gamified CL scenario. This process of extracting this information and how this information is used to setting up the game elements will be detailed in the Chapter 6.

4.3.2 CL Game Dynamic

According to the MDA framework proposed by Hunicke, LeBlanc and Zubek (2004), the "*Game dynamic describes the run-time behavior of the mechanics acting on player inputs and each others' outputs over time*" in which the mechanics describes the particular components of the game, at the level of data representation and algorithms. These mechanics have been represented as game agents in the ontological structures to represent game events as game stimulus and game consequence events in the gamified I_L event. Thus, to describe the run-time behavior of these agents in a chunk of the CL process, in the ontological structure to represent a *Gamified I_L event*, the game events as *game stimulus event* and *game consequence event* include the description of these changes as object produced by the game actions and as states to be achieved by the game actions. The green frame of Figure 55 shows part of the formalization of the run-time behavior of the game agents in the game consequence events of a gamified instructional event. As can be appreciated in the ontological structure to represent the CL Game dynamic, in the game stimulus event, the *object* produced by the game action becomes *Game component*, and the *state* achieved by the game action becomes *Game state*.

The piece of the whole CL process delimited by a gamified I_L event is an interaction defined by the sequencing mechanism of a CSCL script. Thus, to represent the game dynamic in the whole CL process, the concept of "*CL Game dynamic*" has been formalized in the ontology OntoGaCLeS as "*the run-time behavior of the game agents acting to persuade the participants to follow the interactions defined by the sequencing mechanism of a CSCL script*." At the top of Figure 55 is shown the ontological structure to represent the CL Game dynamic in which the necessary and desired interactions are defined as roles that can be played by *Gamified I_L event*. These interactions are defined from interaction patterns formalized in the CL ontology in which the interaction patterns are specialization of CSCL scripts inspired by instructional/learning theories. An example of CL Game dynamic defined for the interaction pattern based on Cognitive Apprenticeship theory is shown at the bottom of Figure 55. In this ontological structure named as "*Gamified Cognitive Apprenticeship type IP*," the necessary interactions are: *Gamified setting up learning context type CA*, *Gamified demonstrating how to solve a problem*, *Gamified monitoring*, and *Gamified affirmative reaction*. The desired interactions are: *Gamified clarifying the problem*, *Gamified notifying how the learner is*, *Gamified instigating thinking*, *Gamified requesting problem's details*, and *Gamified showing a solution type CA*.

Figure 55 – Ontological structure to represent the "*CL Game dynamic*" (at the top). At the bottom, the ontological structure to represent a CL Game dynamic defined for the gamification of Cognitive Apprenticeship interaction pattern.

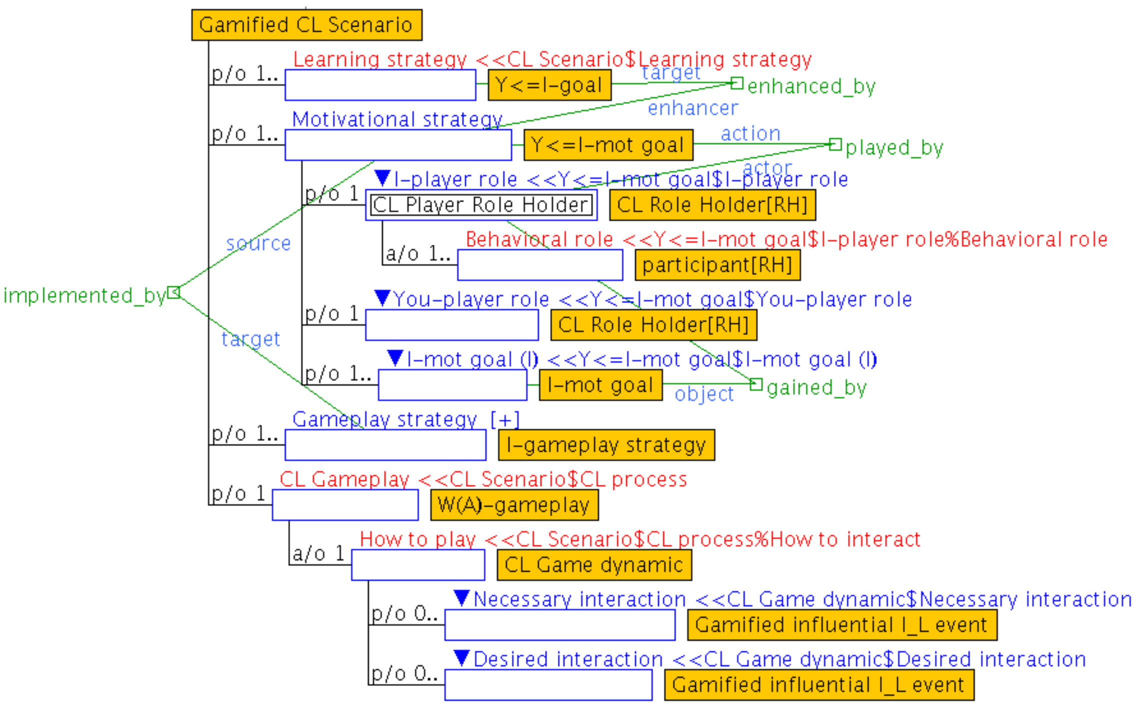
Source: Elaborated by the author.

4.3.3 CL Gameplay

Beside the concept of gameplay is extensively talked in the literature related to game design and gamification, there is no one universally accepted definition of gameplay. According to Fabricatore, Nussbaum and Rosas (2002), gamers talk about gameplay when they refer to their experiences in the game focusing on what the player can do, what the game elements can do in response to the player's actions. Gameplay is the result of a large number of contributing elements (ROLLINGS; ADAMS, 2003), thereby Djaouti *et al.* (2008) defines gameplay as the way in which the players interact with a game elements by means of rules listening input and acting on game elements. These rules through the output system return to the player an evaluation of his performance observing the states of game elements.

As the *CL Game dynamic* describes the run-time behavior of game elements to persuade the participants to follow the sequencing mechanism of a CSCL script, the gameplay of a gamified CL scenario, defined as the concept of "*CL Gameplay*," consists in the set of CL game dynamics defined in this scenario to cause changes in the participants' attitudes, intentions, motivation and/or behaviors. These changes are caused by the gameplay experience of participants interacting with the game elements through the CL Game dynamics. Thus, in the ontological structure to represent a *Gamified CL Scenarios* as shown in Figure 56, the *CL process* is replaced by the *CL Gameplay*, where the information about "*How to interact*" in the CL process described by an *Interaction pattern* is replaced by the *CL Game dynamic* playing the role "*How to play*."

Figure 56 – Ontological structure to represent a "*Gamified CL Scenario*."



Source: Elaborated by the author.

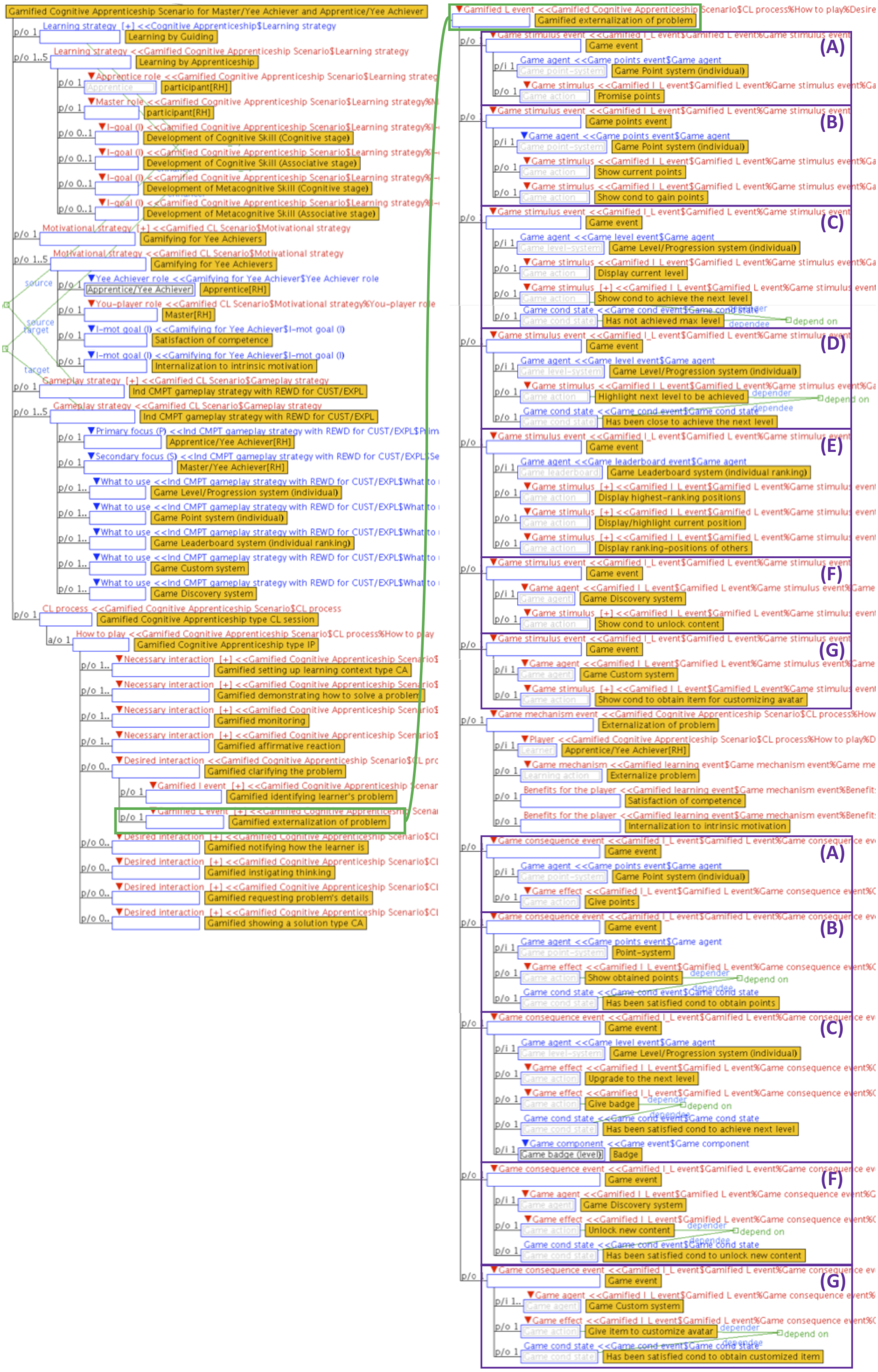
Step (2): Applying persuasive game design strategies in the interaction pattern

The PGDSs identified in the step (1) can be applied in the instructional and learning events to gamify them by the definition of *Persuasive Gameplay Scenario Models* as was detailed in subsection 4.2.3. The PGDSs indicated in the primary focus (P) can be applied in the instructional events of the interaction pattern, and the PGDSs indicated in the secondary focus (S) can be applied in the learning events of the interaction pattern. The application of PGDSs for the pairs of instructional and learner events in an interaction pattern are formalized as gamified I_L events to define the CL Game dynamics of the ontological model being built.

With the information of PGDSs shown in Chart 12, an ontological model to apply gamification as persuasive technology in CL scenarios based on the Cognitive Apprenticeship theory and with the player roles based on the Yee's model has been formalized in the ontology OntoGaCLeS to engender gameplay experiences of individual and cooperative competition. This model consists in the following ontological structures to represent gamified CL scenarios: (1) an ontological structure "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*" to support a CL Gameplay experience of individual competition, (2) an ontological structure *Gamified Cognitive Apprenticeship Scenario for Master/Yee Socializer and Apprentice/Yee Socializer* to support a CL Gameplay experience of cooperative competition, and (3) an ontological structure "*Gamified Cognitive Apprenticeship Scenario for Master/Social Achiever and Apprentice/Social Achiever*" to support a CL gameplay experience of individual and cooperative competition.

Figure 57 shows the ontological structure formalized to represent a *Gamified Cognitive Apprenticeship Scenario for Master/Social Achiever and Apprentice/Social Achiever*. In this structure, the motivational strategy "*Gamify for Yee Achievers*" has been defined as the strategy to enhance the learning strategies "*Learning by Guiding*" and "*Learning by Apprenticeship*" assigned to the master and apprentices, respectively. The motivational strategy "*Gamifying for Yee Achievers*" is implemented by the individual gameplay strategy "*Ind CMPT gameplay strategy with REWD for CUST/EXPL*" to allow the apprentice role holders to attain the *Satisfaction of competence* and *Internalization of intrinsic motivation* defined as individual motivation goals (*I-mot goal*). According to this individual gameplay strategy, to provide an individual competition with rewards for customize avatars and explore new content, the game elements that should be introduced in the CL scenario for apprentices with the Yee achiever role holder are: a *Game Point system (individual)* that is a game point system with individual points, a *Game Level/Progression system (individual)* that is a game level system based on the individual progression of participant, a *Game Leaderboard system (individual ranking)* that is a leaderboard with individual rankings, a *Game Custom system* as a system to provide items for customizing elements of system, and a *Game Discovery system* as a system to provide support for exploring new content in the system.

Figure 57 – Ontological structure to represent a "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever.*"



Source: Elaborated by the author.

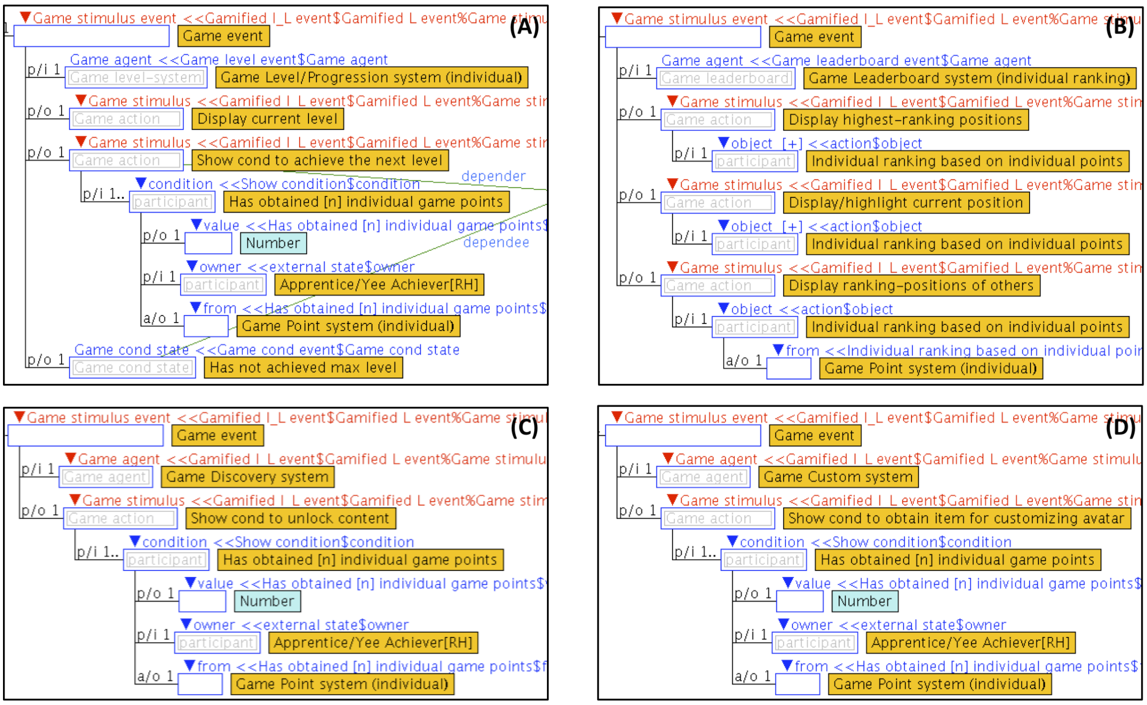
On the right side of Figure 57 is detailed the gamified learning event "*Gamified externalization of problem*" that is result of applying the combination of PGDSs "*SEMT/SUGG, CMPT/CMPR, COOP, PERS, SIM, REWD, CUST*" to gamify the learning event "*Externalization of problem*." The application of the PGDS "*Reward strategy based on PDS*" in the game element "*Game Point system (individual)*" defined the game stimulus and consequence events indicated by the frames (A). According to these events, the game action defined as game stimulus is "*Promise points*," and the game action defined as game effect is: "*Give points*." By applying the PGDSs "*Self-monitoring strategy based on PDS*" and "*Suggestion strategy based on the PDS*" in the game element "*Game Point system (individual)*," the game stimulus and consequence events indicated in the frames (B) were obtained, where the game actions "*Show current points*" and "*Show cond to gain points*" are game stimulus, and the game action "*Show obtained points*" is a game effect. The game actions "*Display current level*" and "*Show cond to achieve the next level*" as game stimulus, and the game action "*Upgrade to the next level*" as game effect were result of applying the PGDSs "*Self-monitoring strategy based on PDS*" and "*Suggestion strategy based on the PDS*" in the game element "*Game Level/Progression system (individual)*". These game stimulus and game effects formalized as game events are shown in the frames (C). By applying the PGDS "*Simulation strategy based on the PDS*" in the game element "*Game Level/Progression system (individual)*," the game stimulus event shown in the frame (D) has been formalized as the game action "*Highlight next level to be achieved*" when a participant *Has been close to achieve the next level*. The game stimulus event shown in the frame (E) with the game actions "*Display highest-ranking positions*," "*Display/highlight current position*" and "*Display ranking-positions of others*" has been obtained by the application of PGDSs "*Competition strategy based on the PDS*" and "*Comparison strategy based on the PDS*" in the game element "*Game Leaderboard system (individual ranking)*." The application of the PGDS "*Personalization strategy based on PDS*" in the game element "*Game Custom system*" defined the game stimulus and consequence events shown in the frames (F), where the game action "*Show cond to unlock content*" is defined as a game stimulus, and where the game action "*Unlock new content*" is defined as game effect. Finally, the game stimulus and consequence events shown in the frame (G) has been obtained by the application of the PGDS "*Customization strategy based on PDS*" in the game element "*Game Discovery system*," where the game action "*Show cond to obtain item for customizing avatar*" is a game stimulus, and the game action "*Give item to customize avatar*" is a game effect.

Step (3): Defining the game states and game components in the CL Game dynamic to provide a gameplay experience according to the individual gameplay strategies

The last step in the formalization of ontological models to apply gamification as persuasive technology consists in the definition of game states and game components in the CL Game dynamic to connect the selected game elements. This connection is also established by setting of the game action in the game stimulus and consequence events. To engender a gameplay experience of individual competition for the Master/Yee Achiever role holders in the "*Gamified*

Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever,” the *Game Level/Progression system (individual)* is connected to the *Game Point system (individual)* by setting of the condition to achieve the next level in the game action “*Show cond to achieve the next level*” as shown in Figure 58 (A), where the condition “*Has obtained [n] individual game points*” is defined as a state to be achieved by the *Apprentice/Yee Achiever role holder* (*owner*) *from* a *Game Point system (individual)*. The game element “*Game Leaderboard system (individual ranking)*” is connected to the “*Game Point system (individual)*” to define individual rankings based on the individual points as shown in Figure 58 (B).

Figure 58 – Connection of game elements to establish a gameplay experience of individual competition in the “*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*.”

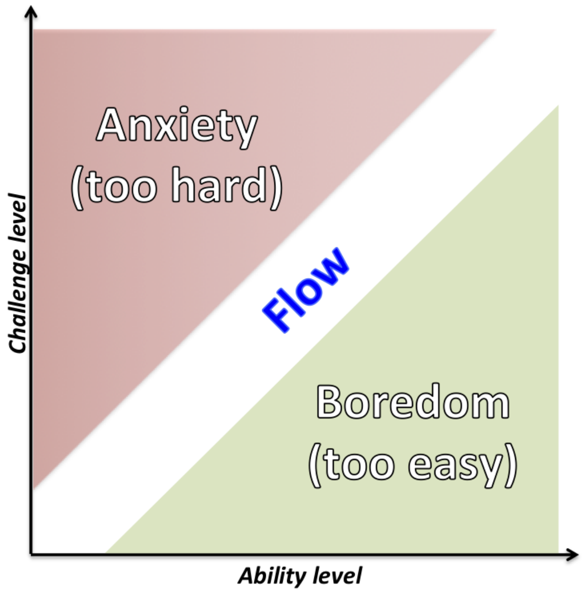


Source: Elaborated by the author.

Figure 58 (C) shows the setting for the connection between the game elements “*Game Point system (individual)*” and “*Game Discovery system*” in which the condition “*Has obtained [n] individual game points*” for the game stimulus “*Show cond to unlock content*” is established as the state own by the *Apprentice/Yee Achiever role holder* (*owner*) given *from* the *Game Point system (individual)*. This connection is defined to unlock new content in the system when the master achiever role holder gained [n] points. The configuration to give items for customizing avatar is show in Figure 58 (D), where the condition to perform the game action “*Show cond to obtain item for customizing avatar*” is that the apprentice achiever role holder “*Has obtained [n] individual game points*.” Thus, the attribute-of (*a/o*) “*from*” has been defined as *Game Point system (individual)*, and the owner role is played by the “*Apprentice/Yee Achiever[RH]*.”

because the person's ability level is not sufficient to solve the task. In the same way, when a task is too easy it causes boredom because it is not challenging enough, or because the person's ability level is too high for the task.

Figure 61 – Affective states in terms of perceived ability level and challenge level, according to the three-channel flow model



Source: Adapted from Csikszentmihalyi (2008).

The three-channel flow model has been frequently used to build instruments and tools for the detection of the flow state (KORT; REILLY; PICARD, 2001; PEARCE; AINLEY; HOWARD, 2005; Esteban-Millat *et al.*, 2014; LEE; JHENG; HSIAO, 2014). More recently, in the context of computer education and instructional technology, studies have attempted to analyze and modeling the flow state in order: (a) to evaluate the participants' interactions with learning objects; (b) to personalize educational activities (e.g. lessons); and (c) to develop better learning content. In the context of game-based learning, a framework to support the integration of games as learning activities is proposed by del Blanco *et al.* (2012). To do so, they identified key aspects about the mechanisms that facilitate the use of pedagogical approaches with games to keep students in the flow state. Then, they proposed a workflow to integrate games into the learning process. As a result, this workflow can be used to create guidelines for helping instructional designers the use (and reuse) of games in the learning process. Although this work provides some initial support for creating better learning experiences using game in the learning process, if the games themselves do not have the qualities and attributes necessary to maintain student engagement, the flow experiences will not occur. Considering this problem, Kiili *et al.* (2014) proposed a framework for analyzing and designing educational games based on the flow theory. This framework describes several dimensions of flow experience as well as meaning factors that affect the design of game-based learning activities.

Despite the broad use of the three-channel flow model in educational contexts and its use in game-based learning, to the best of the knowledge for the author of this dissertation, there is not a computational model based on the three-channel flow model that provides support to create CL scenarios that maintain the flow state in the participants while offering theoretical justifications regarding the learner's growth as an indicator for the perceived ability level. In particular, there is no computational help to define the appropriate levels of challenges for the game elements of a gamified CL scenario.

5.2 Integrating the Learner's Growth Model and the Three-channel Flow Model

The perceived challenge and ability level balance of flow theory can be determined as the current stage of the participant in the LGM model, and the challenge level to maintain the learner in the flow state. Thus, to integrate the representation of the learner's growth process and the condition of good balance between the perceived challenge and ability, the *Learner's **G**rowth **M**odel **I**mproved by **F**low Theory*, hereinafter referred to as GMIF model, has been proposed as a LGM model in which the arrows $s(x_1, y_1) \rightarrow s(x_2, y_2)$ are labeling with the form $[z_{min}; z_{max}]$ to indicate the *minimum challenge level* (z_{min}) and the *maximum challenge level* (z_{max}) that are necessary to maintain the learner's flow.

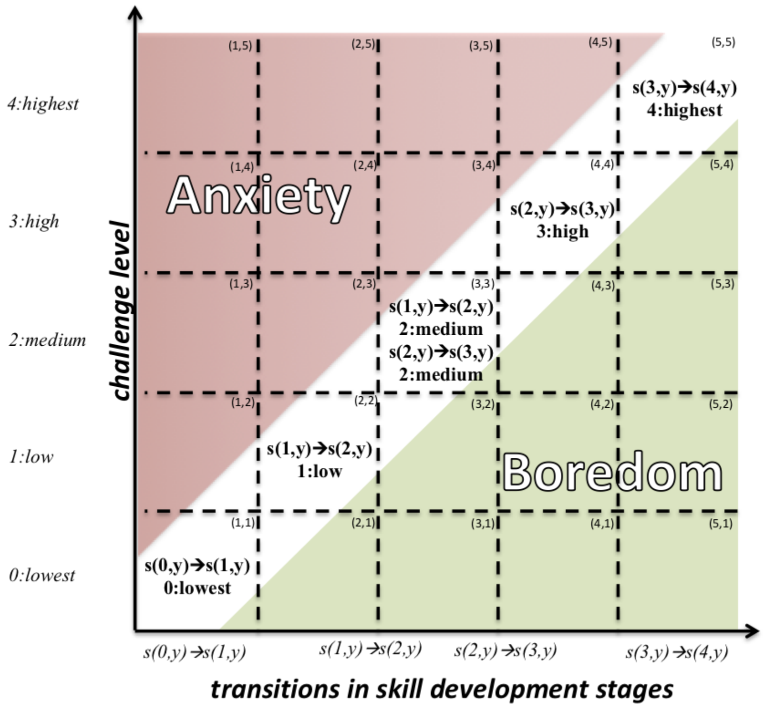
Before to present the algorithm proposed to create a GMIF model with a n-scale of challenge level (*n-scale GMIF model*), a five-scale GMIF model is presented to introduce and detail the elements involved in the building of a GMIF model. After that, the algorithm to create a n-scale GIMF model is presented, and also, the benefits and application of GMIF model in the learning design are detailed.

5.2.1 Five-scale GMIF Model

In the three-channel flow model (detailed in subsection 5.1.2), the levels of perceived challenge and ability are used as indicators to identify the current person's affective state in zones of anxiety, flow, and boredom. These two indicators are represented as axes in the three-channel flow model to depict situations where a learner are anxious, bored or in a flow state. These situations could be represented as a rectangular regions in the plane defined by the division of the perceived challenge and ability axes. Thus, to build a GMIF model, two three-channel flow models with the division of 5×5 rectangular regions are obtained by dividing the axes into five parts. Then, the transitions of the skill development defined by the LGM model are set to the ability axis using a uniform distribution in the first three-channel flow model to define a five-scale three-channel flow model of skill development stages and challenge levels. In the second three-channel flow model, the transitions of the knowledge acquisition defined by the

LGM model are set to the ability axis using also a uniform distribution to define a five-scale three-channel flow model of knowledge acquisition stages and challenge levels.

Figure 62 – Five-scale three-channel flow model of skill development

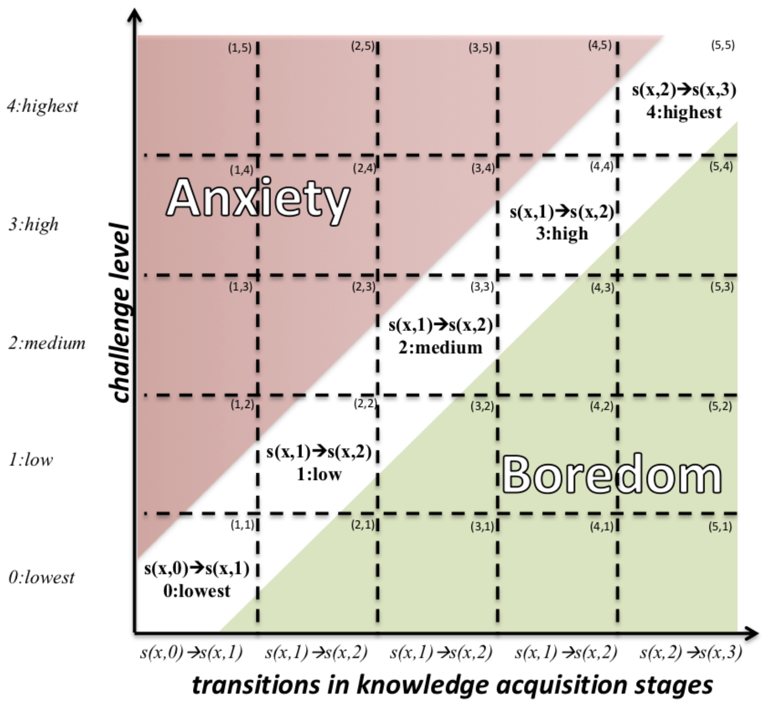


Source: Elaborated by the author.

Figure 62 shows the five-scale three-channel flow model of skill development stages and challenge levels. In this model, the five-scale challenge levels are: 0:*lowest*, 1:*low*, 2:*medium*, 3:*high*, 4:*highest*. The transitions in the skill development are: $s(0,y) \rightarrow s(1,y)$: from *nothing* to *rough-cognitive stage*; $s(1,y) \rightarrow s(2,y)$: from *rough-cognitive stage* to *explanatory-cognitive stage*; $s(2,y) \rightarrow s(3,y)$: from *explanatory-cognitive stage* to *associative stage*; $s(3,y) \rightarrow s(4,y)$: from *associative stage* to *autonomous stage*. According to this model, the label sequence of minimum and maximum challenge levels for maintaining the learner's flow is $s_1 = \{[0;0],[1;2],[2;3],[4;4]\}$ in which the first element "[0;0]" extracted from region $(1,1)$ means that, during the transition: $s(0,y) \rightarrow s(1,y)$, the proper level of challenge to maintain the learner's flow is 0:*lowest*. The second element "[1;2]" extracted from regions $(2,2)$ and $(3,3)$ means that, during the transition $s(1,y) \rightarrow s(2,y)$, the proper level of challenge to maintain the learner's flow is in the range of 1:*low* to 2:*medium*. The third element "[2;3]" means that, during the transition $s(2,y) \rightarrow s(3,y)$ extracted from region $(3,3)$ and $(4,4)$, the proper level of challenge to maintain the learner's flow is in the range of 2:*medium* to 3:*high*. Finally, the fourth element "[4;4]" extracted from region $(5,5)$ means that, during the transition $s(3,y) \rightarrow s(4,y)$, the proper level of challenge is 4:*highest*.

By employing the transitions $s(x,0) \rightarrow s(x,1) \rightarrow s(x,2) \rightarrow s(x,3)$ of knowledge acquisition ($s(x,0) \to s(x,1)$: from *nothing* to *accretion stage*; $s(x,1) \to s(x,2)$: from the *accretion stage* to *tuning stage*; $s(x,2) \to s(x,3)$: from the *tuning stage* to *restructuring stage*), the five-scale three-channel flow model shown in Figure 63 has been obtained to represent the relation of knowledge acquisition stages and challenge levels. In this space, labels of minimum and maximum challenge levels for maintaining the learner's flow is defined by the sequence $s_2 = \{[0;0],[1;3],[4;4]\}$ in which the first element "$[0;0]$" extracted from the region $(1,1)$ means that means that, during the transition $s(x,0) \to s(x,1)$, the level of challenge should be 0:*lowest* to maintain the learner's flow. The second element "$[1;3]$" extracted from regions $(1,1)$, $(2,2)$ and $(3,3)$ means that, during the transition $s(x,1) \to s(x,2)$, the proper level of challenge to maintain the learner's flow is in the range of challenge levels 1:*low*, 2:*medium* and 3:*high*. Finally, the proper level of challenge during the transition $s(x,2) \to s(x,3)$ is 4:*highest*.

Figure 63 – Five-scale three-channel flow model of knowledge acquisition

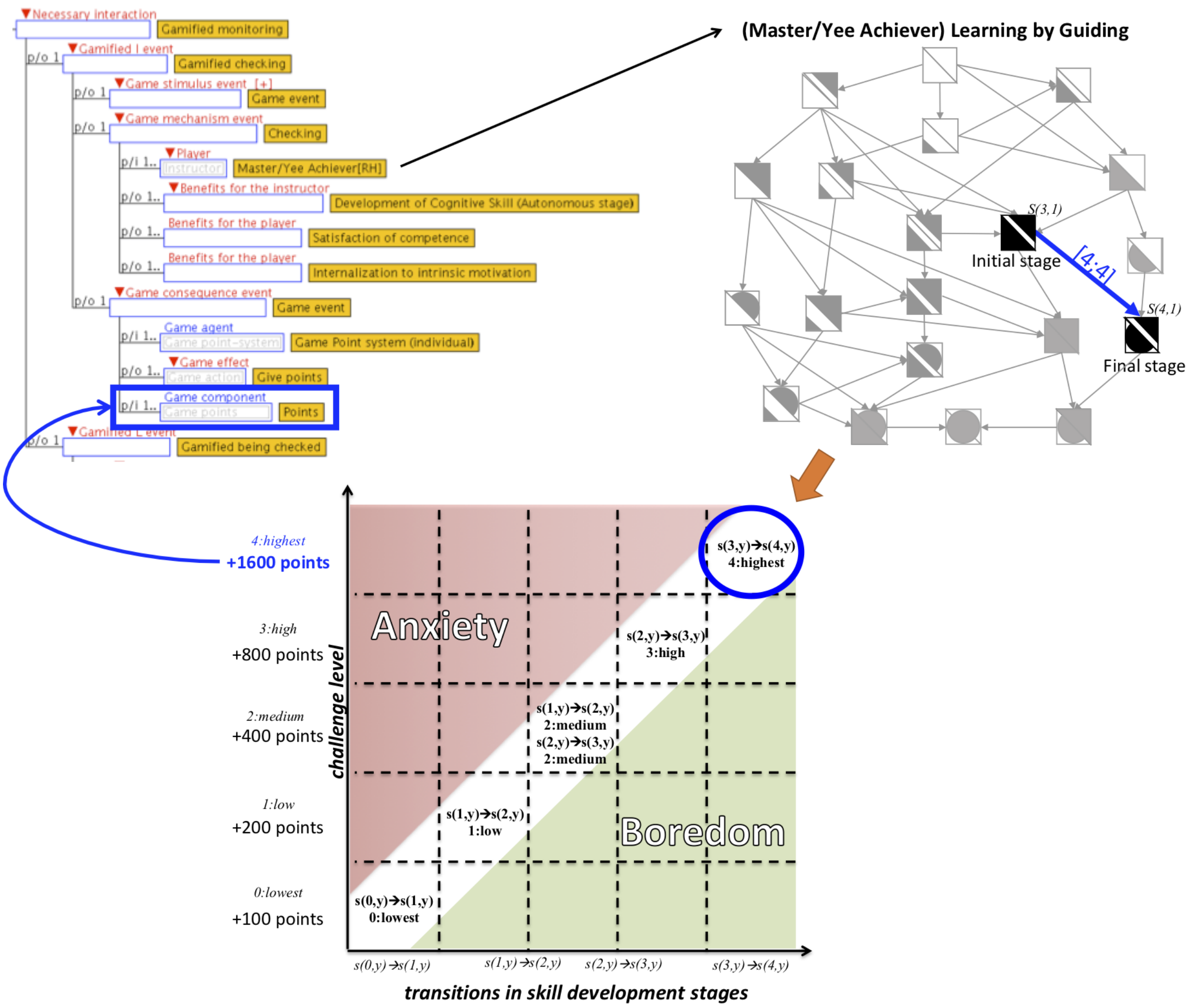


Source: Elaborated by the author.

To obtain the five-scale GMIF model, the relationship between the transitions of stages in the skill development and knowledge acquisition and the challenge levels should be clearly understood from the two five-scale three-channel flow models shown in Figure 62 and Figure 63. With this knowledge, it is possible to design CL scenarios that (i) favor the maintenance of a flow state for students; and (ii) help them to achieve desired educational goals (i.e. acquisition of knowledge or development of skills). To accomplish these objectives, the label sequences (s_1 and s_2) to maintain the learner's flow identified from Figure 62 and Figure 63, which enables us to understand when a participant are in flow state (by making the correlation between knowledge and skills with a five-scale of challenge level), to adequately label each transition (i.e.

the game agent to keep the participant in the flow state.

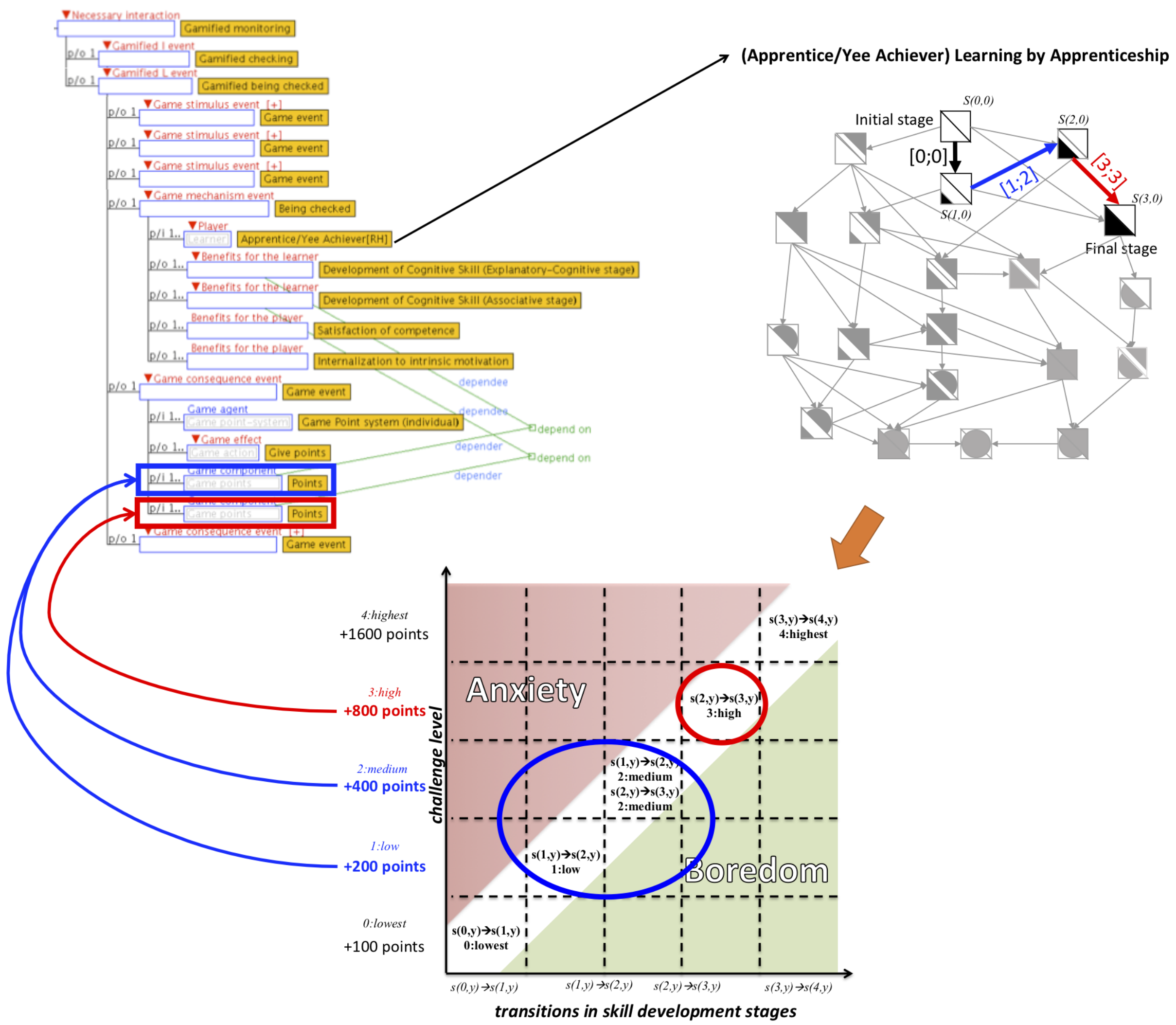
Figure 65 – Application of the GMIF model to set the game points to be given in the gamified instructional event "*Gamified Checking*" of the *Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*



Source: Elaborated by the author.

For the instance shown in Figure 65, where the five-scale GMIF model has been applied to set the game points to be given by the point system as consequence of instructional event "*Checking*" in a gamified CL scenario based on the cognitive apprenticeship theory with the Yee's achiever player role assigned for the master and apprentice role holder - *Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*. In this situation, the instructional designer set the initial stage for the *Master/Yee Achiever* role holder as $s(3,1)$ - associative stage for skill development and accretion for knowledge acquisition - and the goal stage as $s(4,1)$ - autonomous stage for skill development and accretion for knowledge acquisition. Thus, the learning path in the GIMF model is defined by the learning strategy "*Learning by Guiding*," and the proper level of challenges that will favor and maintain the *Master/Yee Achiever* in the flow state is defined by the label "[4;4]" that indicate a 4:*highest* challenge level in the five-scale three-channel flow model of skill development stages. Having this flow region, the proper reward to be given in the *Game consequence event* by *Game Point system (individual)* for the *Master/Yee Achiever* role holder is *+1600 points* (as *Game component*).

Figure 66 – Application of the GMIF model to set the game points to be given in the gamified learning event "*Gamified Being Checked*" of the *Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*



Source: Elaborated by the author.

Figure 66 shows the application of GMIF model to set the game rewards in the gamified learning event "*Gamified Being Checked*." In this example, the learning path identified for the *Apprentice/Yee Achiever* from the initial stage $s(0,0)$ - nothing for skill development and knowledge acquisition - to the goal stage $s(3,0)$ - associative stage for skill development and nothing for knowledge acquisition - is based on the learning strategy "*Learning by Apprenticeship*." By the application of five-scale GMIF model, the label "$[1;2]$" in the transition $s(1,0) \rightarrow s(2,0)$ indicates that the proper challenges levels of 1:*low* and 2:*easy* are necessary to maintain the *Apprentice/Yee Achiever* role holder in the flow state. These challenge levels in the five-scale three-channel flow model of skill development stages correspond to the rewards of *+200 points* or

CHAPTER

6

COMPUTER-BASED MECHANISMS AND PROCEDURES TO GAMIFY COLLABORATIVE LEARNING SESSIONS

The purpose of this chapter is to show how the ontology OntoGaCLeS, and the GIMF model, presented in previous chapters, can be used in intelligent theory-aware systems to gamify CL sessions, and thus, to deal with the motivation problem caused by the scripted collaboration. The section 6.1 presents a conceptual flow to gamify CL sessions proposed as a computer-based procedure that should be used by intelligent theory-aware systems to extract knowledge encoded in the ontology OntoGaCLeS, and then to provide suggestions based on theoretical justification. In section 6.2, a reference architecture based on the conceptual flow to gamify CL sessions is presented. This architecture has been proposed to support the building of computer-based mechanisms that provide support in intelligent-theory aware systems for dealing with the motivation problem caused by the scripted collaboration.

Part of the work described in this chapter was published by the author of this PhD thesis dissertation in the scientific articles:

- "*An Ontology Engineering Approach to Gamify Collaborative Learning Scenarios*" published in the 20th International Conference on Collaboration and Technology, CRIWG 2014, held in Santiago, Chile (CHALLCO *et al.*, 2014).

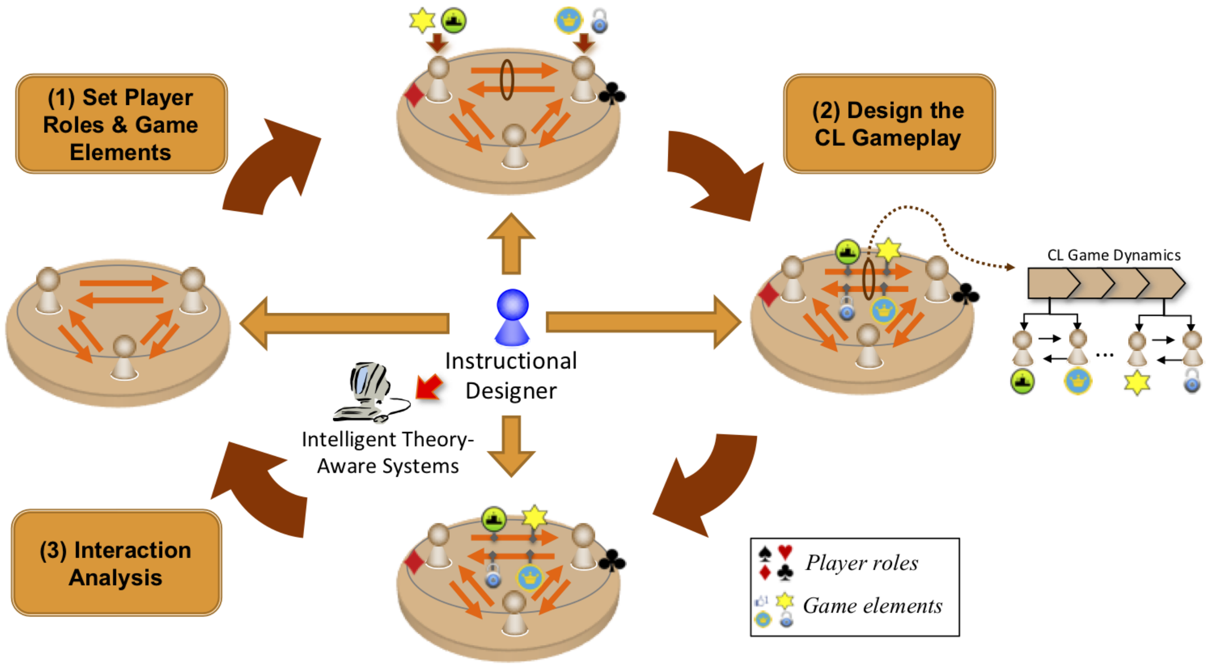
- "*Gamification of Collaborative Learning Scenarios: Structuring Persuasive Strategies Using Game Elements and Ontologies*" published in the 1st International Workshop on Social Computing in Digital Education, SocialEdu 2015, held in Stanford, CA, USA (CHALLCO *et al.*, 2015a).

6.1 Conceptual Flow to Gamify Collaborative Learning Sessions Using the Ontology OntoGaCLeS

To avoid the motivation problem caused by the scripted collaboration by means of the gamification, as was mentioned before (in Chapter 2), it is necessary to solve the context-dependency related to the participants' individual characteristics and traits, and the context-dependency related to the non-game context and target behaviors being gamified. Thus, the gamification should be applied in CL sessions that are the most concrete level of CL scenarios in which the content-domain and participants are well defined, with clear and well-establish group members, CL roles and sequencing of actions to be performed by the group members.

Figure 67 shows the conceptual flow proposed to gamify CL sessions using the ontology OntoGaCLeS. This flow has been developed from the viewpoint of an instructional designer who employs suggestions given by intelligent-theory aware systems, which in turn use the knowledge encoded in the ontology OntoGaCLeS as a source of information to provide these suggestions.

Figure 67 – Conceptual flow to gamify collaborative learning sessions using the ontology OntoGaCLeS



Source: Elaborated by the author.

The basic steps that should be accomplished in the conceptual flow to gamify CL sessions by intelligent-theory aware systems are:

Step (1): to set *player roles* and *game elements* for each participant in the CL session,

Step (2): to design the *CL gameplay* for the CL session, and

Step (3): to perform an *interaction analysis* over the obtained gamified CL sessions.

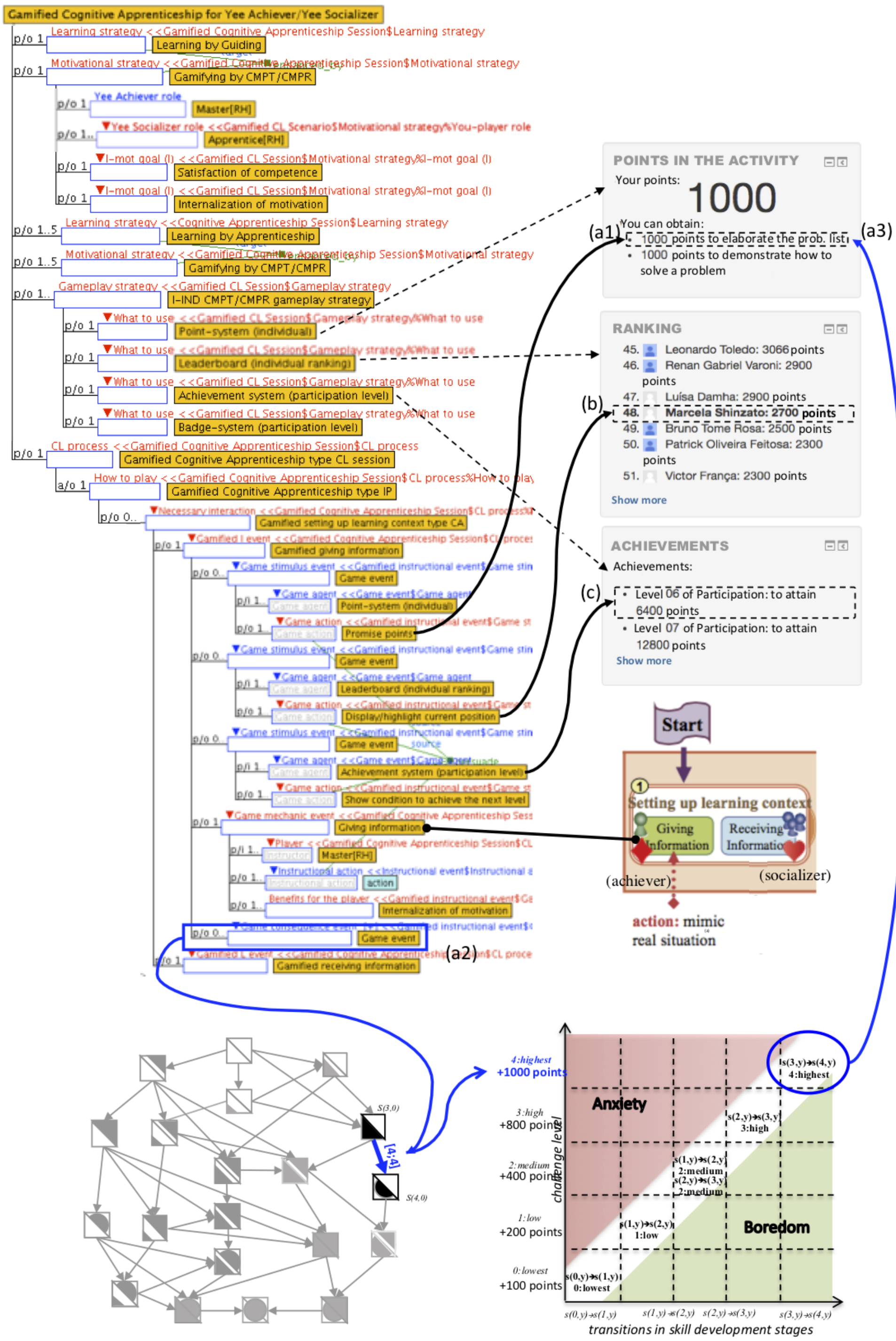
Step (2): Design the CL Gameplay

By setting up the interactions between the selected game elements and the player role holders defined in the step (1), the design of the *CL gameplay* is carried out employing as source the information the gamified I_L events defined as necessary and desired interaction in the CL game dynamics (*How to play*) of CL process refereed as *CL Gameplay* in the ontological structure to represent Gamified CL scenarios. For establishing the value of the game rewards, during the setting of the interactions, the GMIF model can be employed as was detailed in section 5.3.

For a gamified CL session instantiated from a CSCL scripts based on the Cognitive Apprenticeship theory, Figure 68 exemplifies the design of a CL Gameplay for the interaction "*Giving information*" defined as *instructional event*. Thus, before the instructional action, to persuade a master student to give information, the interactions between the game element "*Point-system (individual)*" and the master student is defined as the game action "*Promise points*" in the ontological structure, this game action is implemented as the promise of points to elaborate the prob. list as shown in the the frame (a1), and the quantity of points to be given to the master student after the execution of the instructional action "*give information*" is calculated by the GMIF model as was proposed in section 5.3. For the game consequence event, as shown in the frame (a2), a 5-scale GMIF model has built employing 5-scale of challenge levels (with +100 points to the 0:lowest level, +200 points to the 1:low level, +400 points to the medium level, +800 points to the 3:high level, and +1000 points to the 4:highest level), so that the game reward to be given for the master student after to perform the instructional action to maintain the flow state during the transition $s(3,y) \rightarrow s(4,y)$ should be +1000 points as shown in frame (a3).

To persuade the master students to perform the instructional action, the game stimulus event in the ontological structure defines the game action "*Display/highlight current position*" as the game action that should be performed by the game element "*Leaderboard (individual ranking)*." The implementation of this game action is shown in the frame (b) of Figure 68. The game action "*Show condition to achieve the next level*" defined as game stimulus event for the game element "*Achievement system (participation level)*" has been implemented as shown in the frame (c), in which the game action has been implemented by the message "*Level 06 of Participation: to attain 6400 points*."

Figure 68 – Designing the CL Gameplay in the instructional event "*Giving information*"



Source: Elaborated by the author.

Step (3): Interaction Analysis

Although the game elements are introduced and set-up in a CL session to to change peoples' attitudes, intentions, motivations and/or behaviors through the whole CL process, there is no guarantee that these change occurred during the execution of gamifed CL sessions. Therefore, after the execution of a gamified CL session obtained by intelligent theory-aware systems that uses the ontology OntoGaCLeS, it is necessary to understand what changes occurred while the gamified CL scenario was executed in the learning environment. In this sense, an *interaction analysis* should be carried out with the data gathered from the virtual learning environment in which the gamified CL sessions was executed to identify whether the designed changes occurred satisfactorily. To enable computers to support such a task, it is necessary to use the ontological structures that represent the desired changes in the gamified I_L events, and the changes in real interactions. By doing so, computers can compare the difference between the changes indicated by the ontological structures and the real interactions which helps to create a metric to measure the benefits of gamification and to improve the modeling of gamified I_L events.

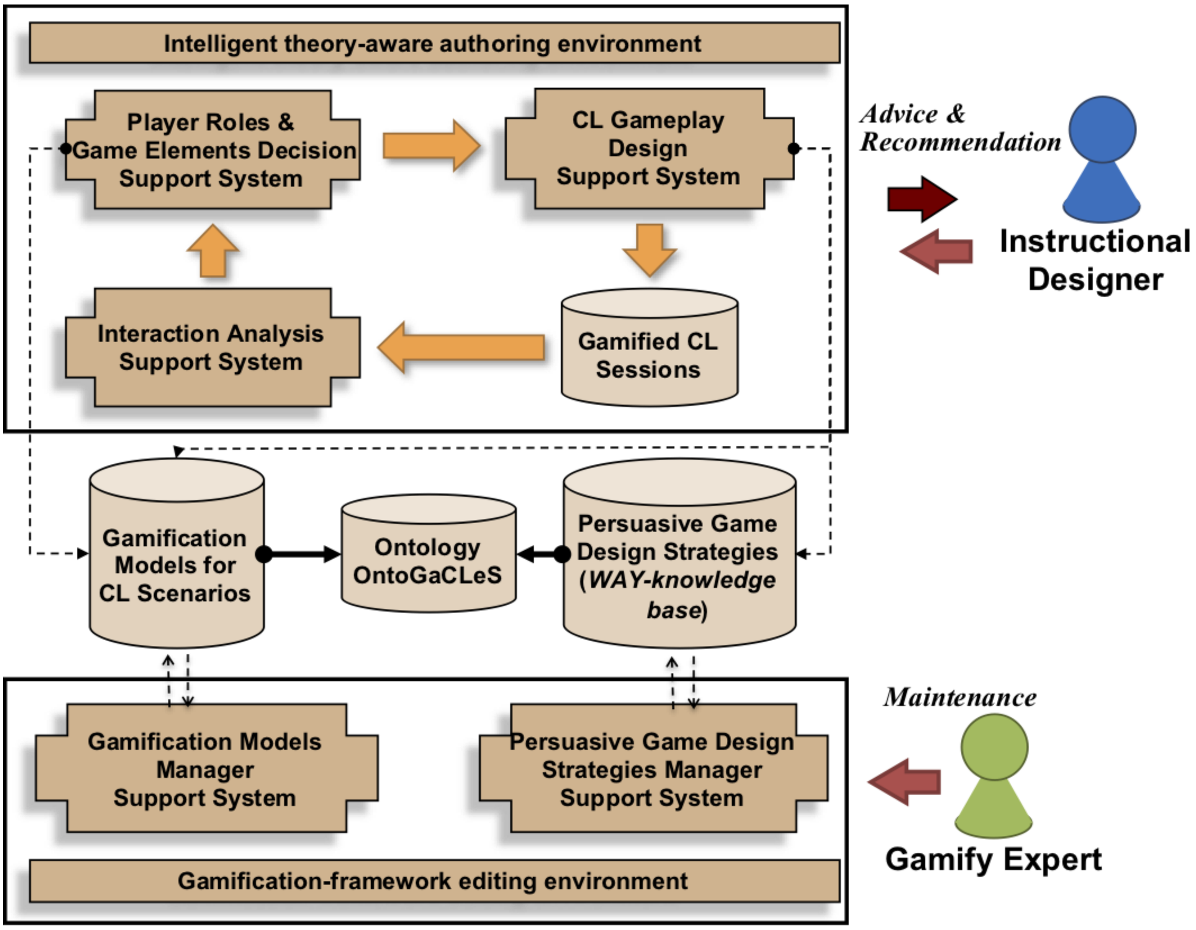
6.2 Reference Architecture of Intelligent-theory Aware Systems that Use the Ontology OntoGaCLeS

Figure 69 shows the proposed reference architecture for building the next generation of intelligent systems, referred to as intelligent theory-aware systems, that can be created and used to deal with the motivation problem by the gamification of CL sessions. This reference architecture aims to help two stakeholders, *instructional designer* and *gamify expert*, to accomplish their activities in two different environments denominated "*Intelligent theory-aware authoring environment*" and "*Gamification-framework editing environment*."

Intelligent Theory-aware Authoring Environment: An environment developed to provide advices and recommendations to help the instructional designer to gamify CL sessions, so that it is composed by three intelligent theory-aware systems, each one of them developed to support one of these step defined in the proposed conceptual flow to gamify CL sessions (section 6.1). In this sense, this environment is composed by the following support-systems:

- A *Player Roles & Game Elements Decision Support System* - as a system that analyzes the profile data of participants in the CL session, and based on this data, helps the instructional designer can make decisions about the player roles that will be assigned for those participants, and which game elements should be introduced in the learning environment to deal with the motivation problem;
- A *CL Gameplay Design Support System* - as a system that, based on the player roles and game elements assigned for the participants of a CL session, provides suggestions to define the interactions between the game elements and participants.

Figure 69 – A reference architecture of intelligent theory-aware systems to gamify CL sessions



Source: Elaborated by the author.

- A *Interaction Analysis Support System* - as a system that, after the execution of gamified CL session, helps the instructional designer to identify whether the designed interactions between the game elements and participants satisfactorily occurred. Thereby, this system requires a Log data that contains information related to the execution of gamified CL sessions in the learning environment.

Intelligent Theory-aware Authoring Environment: An environment in which the gamify expert is supported in the maintenance (creation/update) of ontology-based gamification models for CL scenarios, and the WAY-knowledge base of game design and persuasive game design strategies. Thus, this environment is composed by two support-system:

- A *Gamification Models Manager Support System* - as a system that helps the gamify expert to create and update ontology-based gamification models for CL scenarios. These models are: ontological models to personalize the gamification of CL scenarios (detailed in Chapter 3), and ontological models to apply gamification as persuasive technology (detailed in Chapter 4).

motivation were:

- a Web-based questionnaire for the adapted Portuguese version of the Intrinsic Motivation Inventory (Appendix C: section C.1) employed in the pilot empirical study to gather information related to the participants' intrinsic motivation
- a Paper-based questionnaire for the adapted Portuguese version of the Intrinsic Motivation Inventory (Appendix C: section C.2) employed in the first empirical study to gather information related to the participants' intrinsic motivation
- a Paper-based questionnaire for the adapted Portuguese version of the Instructional Materials Motivation Survey (Appendix C: section C.3) employed in the second empirical study to gather information related to the participants' level of motivation
- a Web-based questionnaire for the adapted Portuguese version of the Intrinsic Motivation Inventory and the adapted Portuguese Instructional Materials Motivation Survey (Appendix C: section C.4) employed in the third empirical study to gather information related to the participants' intrinsic motivation and level of motivation

The ontology-based gamified CL sessions in the empirical studies were obtained through the conceptual flow to gamify CL sessions shown in Figure 67, so that the information encoded in the "*ontological model to apply gamification as persuasive technology in CL scenarios based on the Cognitive Apprenticeship theory and with the player roles based on the Yee's model to personalize the gamification*" has been used with the *Gamification plugins* in the Moodle platform to define the ontology-based gamified CL sessions. However, due to the lack of automatic support given by the Gamification plugins to set and to configure the game elements in the Moodle learning environment, the gamified CL sessions were not obtained using all the three ontological structures to represent gamified CL scenarios described in this model. In this sense, only two of three ontological structures to represent gamified CL scenarios were employed at the same time in each empirical study to set and configure the Gamification plugins, Thus,

- For the pilot, first and second empirical studies, the ontological structures to represent "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*" and "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Socializer and Apprentice/Yee Socializer*" were used to obtain the ontology-based gamified CL sessions.
- For the third empirical study, the ontological structures to represent "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*" and "*Gamified Cognitive Apprenticeship Scenario for Master/Social Achiever and Apprentice/Social Achiever*" were used to obtain the ontology-based gamified CL sessions.

Finally, in all the types of CL sessions (ont-gamified CL sessions, non-gamified CL sessions, and w/o-gamified CL sessions), a CSCL script inspired by the Cognitive Apprenticeship theory and illustrated in Figure 28 was used as a method to orchestrate and structure the collaboration among the participants. This script was implemented as an activity in the Moodle platform by employing the *Scripting-forum module*[3].

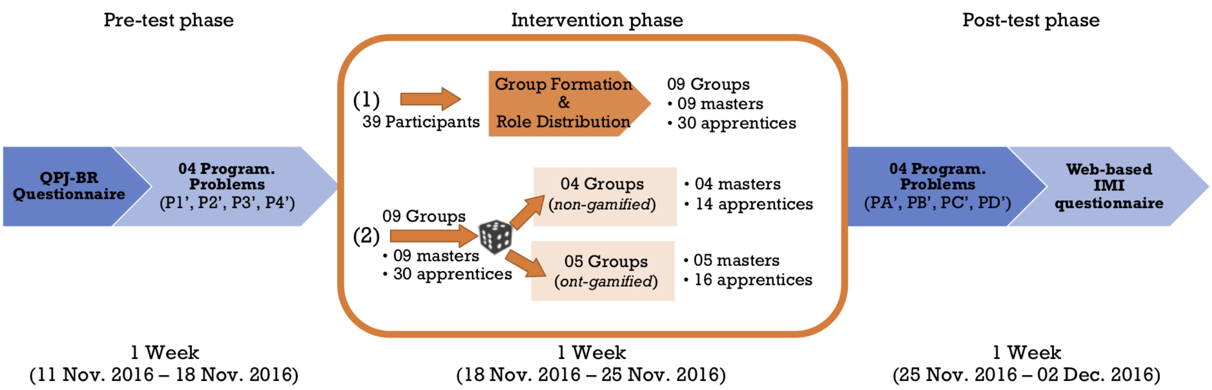
7.1.7 Schedule, Timing, and Data Collection Procedure

Preparation: The aspects under study in the empirical studies and the hypotheses stated in this dissertation were not informed to the participants (students) of the empirical studies, but they were aware that the researcher wanted to use the data gathered by their participation in the course. All participants (students) were guaranteed anonymity, and all materials that were used in the data collection procedure were prepared in advance. Previously to the intervention phase, as part of the preparation phase, the students were instructed in how to participate in the CL activity using the *Scripting-forum module* in the Moodle platform.

7.1.7.1 Execution: Pilot Empirical Study

The pilot empirical study was executed over three weeks with the schedule, timing and data collection procedure shown in Figure 72.

Figure 72 – Diagram of the schedule, timing and data collection procedure in the pilot empirical study



Source: Elaborated by the author.

During the pre-test phase (1 week), from 11 November 2016 to 18 November 2016, the Web-based QPJ-BR questionnaire has been answered by all the participants through the Moodle platform using the *Questionnaire module*[4]. During this phase, to gather data related to the skill/knowledge, four programming problem tasks (P1', P2', P3', and P4' - detailed in Table 2) have also been solved by the students in the Moodle platform using the VPL module.

[3] Available at the URL: <https://github.com/geiser/moodle_scripting_forum>
[4] Available at the URL: <https://github.com/geiser/moodle-mod_questionnaire>

During the intervention phase (1 week), from 18 November 2016 to 25 November 2016, the 39 students participated in either non-gamified CL sessions or ontology-based gamified CL sessions. These students were formed into 9 groups of 4 or 5 members with 9 masters and 30 apprentices assigned according to the theory-driven group formation (ISOTANI; MIZOGUCHI, 2008b). Four of these nine groups participated in non-gamified CL sessions, and five groups participated in ontology-based gamified CL sessions.

The ontological structures to represent "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*" and "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Socializer and Apprentice/Yee Socializer*" were used to obtain the ontology-based gamified CL sessions in which:

- The students who had more liking for achievement-components than positive liking for social-components were assigned to play the *Yee Achiever role* in gamified CL sessions instantiated from the ontological structure "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*" to support a CL Gameplay experience of *individual competition*.

- The students who had more positive liking for social-components than positive liking for achievement-components were assigned to play the *Yee Socializer role* in gamified CL sessions instantiated from the ontological structure "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Socializer and Apprentice/Yee Socializer*" to support a CL Gameplay experience of *cooperative competition*.

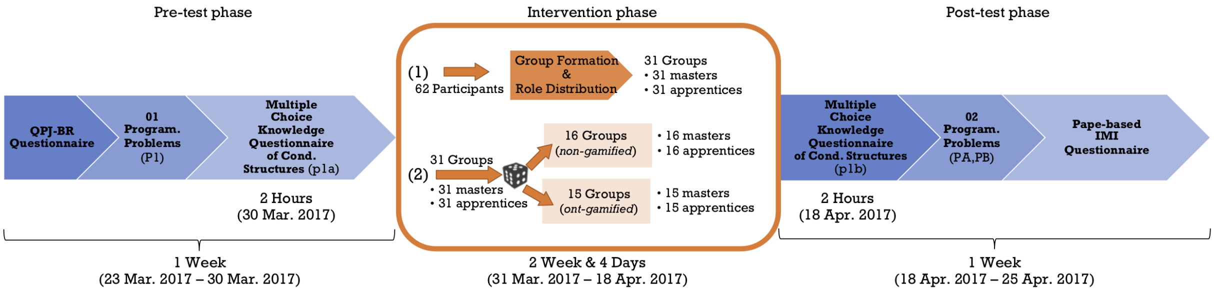
During the post-test phase (1 week), from 25 November 2016 to 02 December 2016, to gather data related to the skill/knowledge, four programming problem tasks (PA', PB', PC', and PD' - detailed in Table 2) have been solved by the students in the Moodle platform using the VPL module. The students also answered the IMI questionnaire through the Moodle platform using the *Questionnaire module* to gather data related to the participants' intrinsic motivation.

7.1.7.2 Execution: First Empirical Study

The first empirical study was executed over four weeks and four days with the schedule, timing and data collection procedure shown in Figure 73.

During the pre-test phase (1 week), from 23 March 2017 to 30 March 2017, to gather information of students' preference related to their liking for game-components, the Web-based QPJ-BR questionnaire has been answered by all the participants through the Moodle platform using the *Questionnaire module*. Data related to the participants' initial skill/knowledge were gathered from one programming problem task (P1) and one multiple choice knowledge questionnaire of conditional structures (p1a), both instruments are detailed in Table 2. The programming problem task (P1) was solved by the students in the Moodle platform using the

Figure 73 – Diagram of the schedule, timing and data collection procedure in the first empirical study



Source: Elaborated by the author.

VPL module, and the students answered the multiple choice knowledge questionnaire (p1a) - during 2 hours on March, 30th - at the classroom in the University of São Paulo as a formative evaluation in the course of Introduction to Computer Science.

During the intervention phase (2 weeks & 4 days), from 31 March 2017 to 18 April 2017, the 62 students participated in either non-gamified CL sessions or ontology-based gamified CL sessions. These students were formed into 31 groups of 2 members with 31 masters and 31 apprentices assigned according to the theory-driven group formation (ISOTANI; MIZOGUCHI, 2008b). Sixteen of thirty one groups participated in non-gamified CL sessions, and fifteen groups participated in ontology-based gamified CL sessions.

The ontological structures to represent "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*" and "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Socializer and Apprentice/Yee Socializer*" were used to obtain the ontology-based gamified CL sessions in which:

- The students who had more liking for achievement-components than positive liking for social-components were assigned to play the *Yee Achiever role* in gamified CL sessions instantiated from the ontological structure "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*" to support a CL Gameplay experience of *individual competition*.

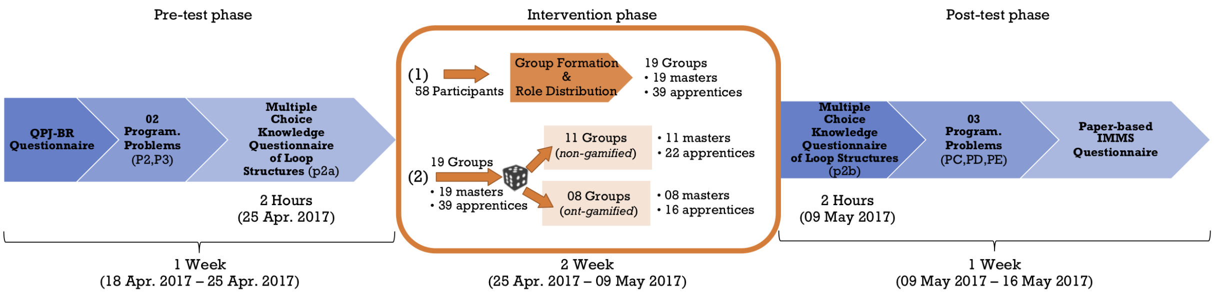
- The students who had more positive liking for social-components than positive liking for achievement-components were assigned to play the *Yee Socializer role* in gamified CL sessions instantiated from the ontological structure "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Socializer and Apprentice/Yee Socializer*" to support a CL Gameplay experience of *cooperative competition*.

During the post-test phase (1 week), from 18 April 2017 to 25 April 2017, to gather data related to the skill/knowledge, the multiple choice knowledge questionnaire of conditional structures (p1b) was answered by the participants - during 2 hours on April, 18th - at the classroom in the University of São Paulo as a formative evaluation in the course of Introduction to Computer Science. Two programming problem tasks (PA, PB - detailed in Table 2) have been solved by the students in the Moodle platform using the VPL module. The students also answered the paper-based IMI questionnaire at the classroom in the University of São Paulo to gather data related to the students' intrinsic motivation.

7.1.7.3 Execution: Second Empirical Study

The second empirical study was executed over four weeks with the schedule, timing and data collection procedure shown in Figure 74.

Figure 74 – Diagram of the schedule, timing and data collection procedure in the second empirical study



Source: Elaborated by the author.

During the pre-test phase (1 week), from 18 April 2017 to 25 April 2017, students' preference related to their liking for game-components were gathered through a paper-based QPJ-BR questionnaire answered by all the students in the Moodle platform using the *Questionnaire module*. Data related to the participants' initial skill/knowledge were gathered from one programming problem task (P2, and P3 - detailed in Table 2) and one multiple choice knowledge questionnaire of loop structures (p2a). The students solved the programming problem tasks in the Moodle platform using the *VPL module*, and they answered the multiple choice knowledge questionnaire (p2a) - during 2 hours on April, 25th - at the University of São Paulo as a formative evaluation in the course of Introduction to Computer Science.

During the intervention phase (2 weeks), from 25 April 2017 to 9 May 2017, the 58 students participated in either non-gamified CL sessions or ontology-based gamified CL sessions. These students were formed into 19 groups of 3 members with 19 masters and 39 apprentices assigned according to the theory-driven group formation (ISOTANI; MIZOGUCHI, 2008b). Eleven of nineteen groups participated in non-gamified CL sessions, and eight groups participated in ontology-based gamified CL sessions.

The ontological structures to represent "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*" and "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Socializer and Apprentice/Yee Socializer*" were used to obtain the ontology-based gamified CL sessions in which:

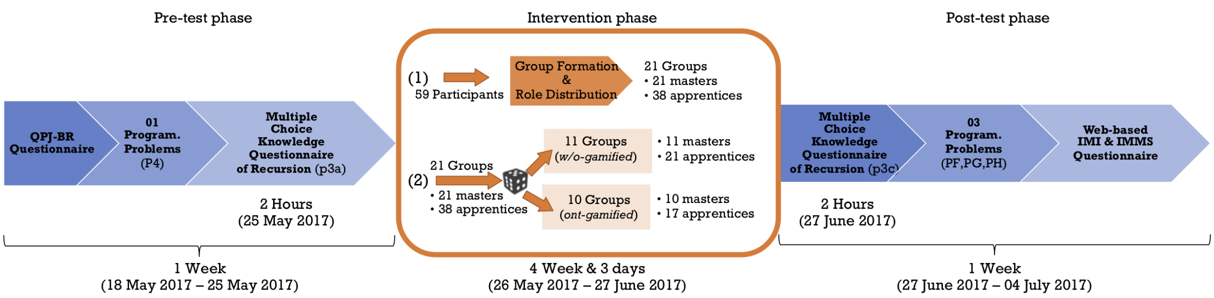
- The students who had more liking for achievement-components than positive liking for social-components were assigned to play the *Yee Achiever role* in gamified CL sessions instantiated from the ontological structure "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*" to support a CL Gameplay experience of *individual competition*.
- The students who had more positive liking for social-components than positive liking for achievement-components were assigned to play the *Yee Socializer role* in gamified CL sessions instantiated from the ontological structure "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Socializer and Apprentice/Yee Socializer*" to support a CL Gameplay experience of *cooperative competition*.

During the post-test phase (1 week), from 9 May 2017 to 16 May 2017, to gather data related to the skill/knowledge, the multiple choice knowledge questionnaire of loop structures (p2b) was answered by the students - during 2 hours on May, 9th - at the classroom in the University of São Paulo as a formative evaluation in the course of Introduction to Computer Science. Three programming problem tasks (PC, PD, PE - detailed in Table 2) have been solved by the students in the Moodle platform using the VPL module. To gather data related to the participants' level of motivation, the students answered the paper-based IMMS questionnaire at the classroom in the University of São Paulo.

7.1.7.4 Execution: Third Empirical Study

The third empirical study was executed over six weeks and three days with the schedule, timing and data collection procedure shown in Figure 75.

Figure 75 – Diagram of the schedule, timing and data collection procedure in the third empirical study



Source: Elaborated by the author.

During the pre-test phase (1 week), from 18 May 2017 to 25 May 2017, the Web-based QPJ-BR questionnaire were answered by all the participants through the Moodle platform using the *Questionnaire module*. To gather data related to the skill/knowledge, students solved one programming problem task (P4) in the Moodle platform using the VPL module, and they answered the multiple choice knowledge questionnaire of recursion (p3a) at the classroom in the University of São Paulo - during 2 hours on May 25th.

7.6 Interpretation and Implications of Obtained Results

Previous sections emphasize, in an independent way, the results obtained in each one of the empirical studies conducted in this dissertation. However, nothing in reference to the global contribution, the ontological engineering approach to gamify CL scenarios as an effective and efficient solution to deal with the motivation problem caused by the scripted collaboration, has been carried out. In this section, a cross-analysis is undertaken to revise the relationships across the results obtained in the empirical studies, and to demonstrate the effectiveness and efficiency. Thus, the objective of this cross-analysis is to make assertions about the effects of ontology-based gamified CL sessions (*ont-gamified*), non-gamified CL sessions (*non-gamified*), and CL sessions that were gamified without using the support given by the ontology OntoGaCLeS (*w/o-gamified*) on participants' motivation and learning outcomes, and the relationships between these effects.

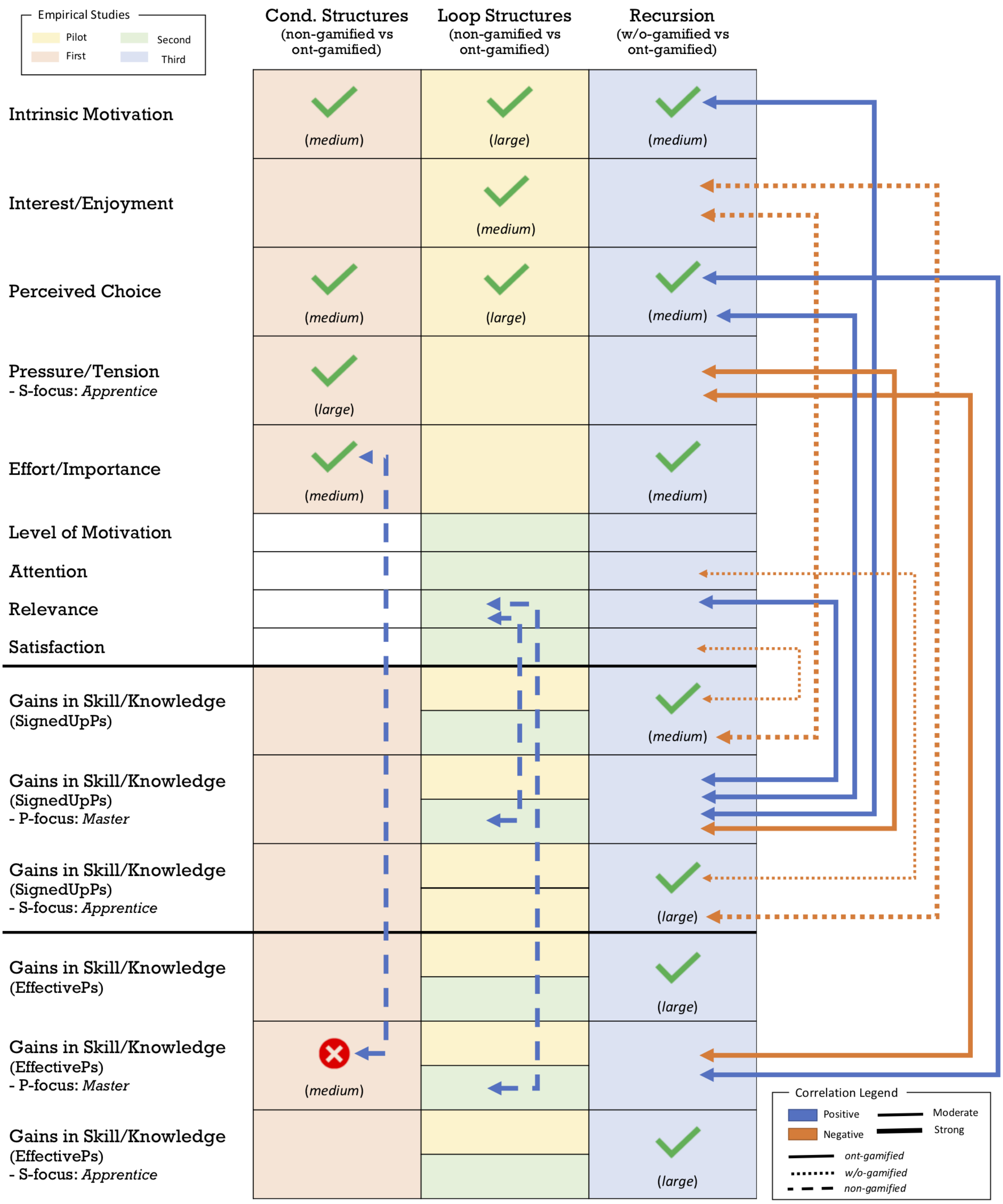
Figure 76 shows the graphical representation of the cross-analysis carried out with the significant differences and correlations found in the empirical studies for the participants' motivation and learning outcomes. Taking into account that the topics addressed as content-domain in the CL activities, from the easiest to the hardest level of difficulty, were: conditional structures, loop structures, and recursions; the inferred assertions on this cross analysis are:

Assertion (1): The ontological engineering approach to gamify CL scenarios is an effective method to deal with the motivation problem caused by the scripted collaboration because the ont-gamified CL sessions as the final product obtained by this approach significantly have better participants' perceived choice and intrinsic motivation than non-gamified CL sessions.

As was indicated by Challco *et al.* (2014), Isotani (2009), in CL activities where the CSCL scripts are used as a method to orchestrate and structure the collaboration among the participants, the motivation problem can occur when the participants have a sense of obligation in complete an unwilling activity by the lack of choice over the sequence of interaction. In this sense, increasing the participants' perceived choice in CL sessions instantiated from CSCL scripts avoids the motivation problem, and the ont-gamified CL sessions obtained through the ontological engineering approach to gamify CL sessions have been demonstrated to be an efficient method to accomplish this task. The pilot and first empirical studies demonstrated this effectiveness by indicating that the participants' perceived choice in ont-gamified CL sessions was significantly greater than in non-gamified CL sessions with large and medium effect sizes.

The internalization of motivation has been defined by the SDT theory (RYAN; DECI, 2000) as an internal psychological change that occurs, from a non-freely choice of behaviors or actions to a freely choice by oneself, when a person is intrinsic motivated. In this sense, this change should occur to avoid the motivation problem because, when the participants act following the interaction defined by scripts in a non-freely choice, they will be led to a demotivation stage, which makes more difficult to participate in CL sessions instantiated from CSCL scripts over time. Then, ensuring that the participants are more intrinsic motivated in ont-gamified CL sessions than in non-gamified CL session is an evidence that these sessions intend to avoid the motivation problem in an effective way. This fact has been demonstrated in the pilot and first empirical studies where the participants' intrinsic motivation in ont-gamified CL sessions were greater that in non-gamified CL sessions with large and medium effect sizes.

Figure 76 – Cross-analysis of significant differences and correlations found in empirical studies for the participants' motivation and learning outcomes



Source: Elaborated by the author.

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