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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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Gamificação de Cenários de Aprendizagem Colaborativa: Uma Abordagem de Engenharia de Ontologias para Lidar com o Problema de Motivação Causado por Scripts de Aprendizagem Colaborativa Suportados por Computador

Tese apresentada ao Instituto de Ciências Matemáticas e de Computação – ICMC-USP, como parte dos requisitos para obtenção do título de Doutor em Ciências – Ciências de Computação e Matemática Computacional. *EXEMPLAR DE DEFESA*

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CHAPTER

1

INTRODUCTION

This chapter starts with the context and delimitation of research problem (section 1.1). After that, the chapter formulates the research questions and objectives (section 1.2). The research methodology is presented in section 1.3. The thesis statement and contributions are presented in section 1.4. The chapter ends with the structure of this dissertation (section 1.5).

1.1 Context and Problem Delimitation

Over the last two decades or so, with the growing number of technologies that enable people to communicate and work in group activities using computers and Internet, researches and practitioners have developed technology and software applications that facilitate and foster the Collaborative Learning (CL) (LEHTINEN *et al.*, 1999). Such technology and the research field that studies how to effectively link together the advanced in computer science with the collaborative learning is known as Computer-Supported Collaborative Learning (CSCL), and it has been proved an important to support the learning process of students by cognitive, social and technological reasons (STAHL; KOSCHMANN; SUTHERS, 2006). However, CSCL is only beneficial when there is an adequate design establishing the way in which the collaboration should happened (DILLENBOURG, 2013; HEWITT, 2005; ISOTANI *et al.*, 2009). Students frequently fail to be engaged in productive learning interactions when they are left to interact in CL activities without any support. Hence, several researchers propose the use of scripts to guide and orchestrate the collaboration among students (ALHARBI; ATHAUDA; CHIONG, 2014).

Scripted collaboration aims to engage the students in fruitful and meaningful interactions according to a design that has the purpose to attain a set of pedagogical objectives. Thereby, CSCL scripts have been proposed by the community to support the well-thought-out design of the CL scenarios by means of computer-based systems (FISCHER *et al.*, 2013; KOBBE *et al.*, 2007). These scripts are the technology that describes how the interactions among students will be orchestrated in a group activity to increase the possibility of achieving the pedagogical objectives (WEINBERGER *et al.*, 2005). These scripts provide information that facilitates the group formation, the role distribution, and the sequencing of interaction for the participants of a CL activity. Despite of these benefits, there are situations in which the scripts may cause motivation problem. Sometimes, a learner does not want to play the role assigned by the scripts, and he may neglect his personal behavior to get the task completed without effort and, other times, the lack of choice over the sequence of interactions may produce in the students a sense of obligation in complete an unwilling activity (CHALLCO *et al.*, 2014; ISOTANI, 2009). These issues may negatively influence the students' motivation, learning attitudes and behaviors, degrade the classroom group dynamics, and result in long-term and widespread negative learning outcomes (CHALLCO *et al.*, 2014; FALOUT; ELWOOD; HOOD, 2009)

The motivation problem caused by the scripted collaboration makes more difficult the use of CSCL technology over time. In fact, less motivated students prefer to spend more time in other activities rather than to learn and, as consequence, the achievement of expected learning outcomes becomes difficult (CROOK, 2000; SCHOOR; BANNERT, 2011). In this sense, motivating learners in the entire instructional process of CL is important. However, the traditional instructional design practice assumes that the motivation is a simple preliminary step that must happen before the instruction (CHAN; AHERN, 1999; KELLER, 1987). This assumption is based in which the good quality of learning materials can keep the students focused during the learning process, but if this process is long, there is a good chance that the students will lose their initial attention. To solve this problem, several approaches, such as the use of affective feedbacks based on emotion-aware (FEIDAKIS *et al.*, 2014b; FEIDAKIS *et al.*, 2014a), peer learning companions (WOOLF *et al.*, 2009), and so on, have been proposed to motivated students along the entire instructional process. These solutions assume that the students like the content-domain and/or have the desired to learn, so that students that do not have the desire to learn are not motivated and engage for these approaches.

In the last years, efforts of CSCL community have been directed to finding new innovative solutions that, beside to motivate and engage students during the entire CL process, are not completely tied to the domain-content and desired to learn the domain-content. In this direction, several researchers and practitioners have pointed Gamification as a promising technology to deal with motivation problem in the instructional/learning domain (CHALLCO *et al.*, 2014; SEABORN; FELS, 2015; de Sousa Borges *et al.*, 2014). Gamification defined "*as the use of game design elements in non-game contexts*" (DETERDING *et al.*, 2011) aims to increase the students' motivation and engagement by making the learning process more game-like. This is done through the introduction of game elements, such as points, leaderboards, competition, cooperation and so on. These elements are not part of the domain-content, neither they belong to the instructional/learning process, so that they can even motivate students who do not have the desire and/or interest in to learn the content-domain. These game elements are introduced along the entire learning process, so that the benefits of gamification strongly depend on how well these game elements are applied, and how well they are linked with the pedagogical approaches

(KAPP, 2012; KNUTAS *et al.*, 2014b).

When CL scenarios are gamified to deal with the motivation problem caused by the scripted collaboration, the author of this thesis hypothesizes that the chances to achieve engagement and educational benefits will be increased whether there is a proper connection between the game elements and the CL process. Nevertheless, developing such well-though-out gamified CL scenario, hereinafter referred to as gamified CL scenarios, is not trivial. The main difficulty to gamify CL scenarios as well as other non-game context is that the gamification is too context dependent (HAMARI; KOIVISTO; SARSA, 2014; RICHARDS; THOMPSON; GRAHAM, 2014). Its effects vary individual to individual, and they depend of many factors such as the individual personality traits, preferences, and current students' emotions (NICHOLSON, 2015; PEDRO *et al.*, 2015) (e.g., a user who likes competition would be more motivated by a leaderboard rather than a user who want to obtain items to customize his/her avatar). Also, the expected effects of the game elements vary according to the non-game context and target behavior that is being gamified (DETERDING *et al.*, 2013; HEETER *et al.*, 2011) (e.g., gamifying a learning scenario to promote the sign-up of participants is not the same that gamifying an interactive enviroment to maintain the students attention). As consequence of this context-dependency, when a CL scenario is not well gamified, instead to have a positive effect, they may cause a detrimental on the students' motivation (ANDRADE; MIZOGUCHI; ISOTANI, 2016), cheating (NUNES *et al.*, 2016), embarrassment (OHNO; YAMASAKI; TOKIWA, 2013), and lack of credibility on badges (DAVIS; SINGH, 2015).

Another difficulty to gamify CL scenarios, as well as other non-game contexts, it is the lack of approaches to systematically represent, in an unambiguous way, the gamification knowledge acquired in the last years by researchers and practitioners. This knowledge constituted by theories and best practices related to gamification lacks of a formal and common vocabulary, definitions, and representation to apply gamification. As can be appreciated in the current literature of gamification (DICHEVA *et al.*, 2015; HAMARI; KOIVISTO; SARSA, 2014; MORA *et al.*, 2015; SEABORN; FELS, 2015), each author proposes his/her own definitions, classifications and representation to describe the concepts and characteristics about how to gamify a non-game context. This fact hinders the creation of models and/or frameworks that formally represent the gamification and its application by computer-based systems in a common understandable and sharable manner, and to the best of the thesis author's knowledge, there are no one approaches has been proposed to represent the knowledge about how to gamify CL scenarios to deal with the motivation problem caused by the scripted collaboration.

Due to the variety of students who can participate in CL sessions, the diversity of subjects that can be under study in a CL activity, and the range of different CSCL scripts that can be used to orchestrate the CL process, it is necessary to personalize the gamification, providing a tailored gamified CL scenario for each situation. This task is difficult and time-consuming, so that developing a computational based-support in intelligent-theory aware systems to give assistance with the personalization of gamification is very helpful and necessary. In this direction, in the context of CSCL, one interesting solution has been proposed to gamify CL scenarios using adaptive profiles and machine learning techniques (KNUTAS *et al.*, 2014a; KNUTAS *et al.*, 2014b). However, this solution is not oriented to deal with the motivation problem caused by the scripted collaboration, its purpose is to increase the communication among the participants in CL scenarios. Furthermore, this solution falls into the category of computer-based mechanisms and procedures that support the gamification, it does not provide a model to share the theoretical knowledge related to gamification obtained by this computer-based mechanism. Solutions based on machine learning to personalize gamification require a lot of data to support the personalization of gamification, and they may have overfitting or underfitting problem with the data. A computer mechanism based only in machine learning techniques to personalize gamification lacks of theoretical-justification to explain why a game element is introduced, and why a certain configuration of game elements increases the motivation participants in a CL scenario.

For the reason exposed above, to deal with the motivation problem caused by the scripted collaboration through the gamification of CL scenarios, a computational support with a common and shareable structure to describe knowledge extracted from the best practices and theories related to gamification is essential to overcome the challenges and difficulties of gamification. In the direction to make explicit the knowledge contained in computer-based mechanisms and procedures, ontologies have been consolidated as the most advanced technology to support the representation of knowledge in a common computer-understandable and sharable manner (ASIKRI *et al.*, 2016; DEVEDŽIC, 2006; MIZOGUCHI; BOURDEAU, 2016). Ontologies constitute an explicit mapping between the target world of interest and its representation with the purpose to describe concepts without ambiguities providing a common way to represent the knowledge (GUARINO; OBERLE; STAAB, 2009). Taking advantages of this commonality, and using the computer interconnection technologies such as Internet, computer-based mechanisms in intelligent systems use ontologies to share understandings and interpretations of target world. In this direction, employing ontologies, some interesting and practical results have been obtained in the formalization and organization of knowledge extracted from different theories and practices related to gamification (DERMEVAL *et al.*, 2016; KARKAR; JA'AM; FOUFOU, 2016; ZOUAQ; NKAMBOU, 2010). However, currently, there is no one ontology that allows the description of fundaments concepts extracted from the best practices and theories related to gamification, and how these concepts are applied in CL scenarios to deal with the motivation problem caused by the scripted collaboration.

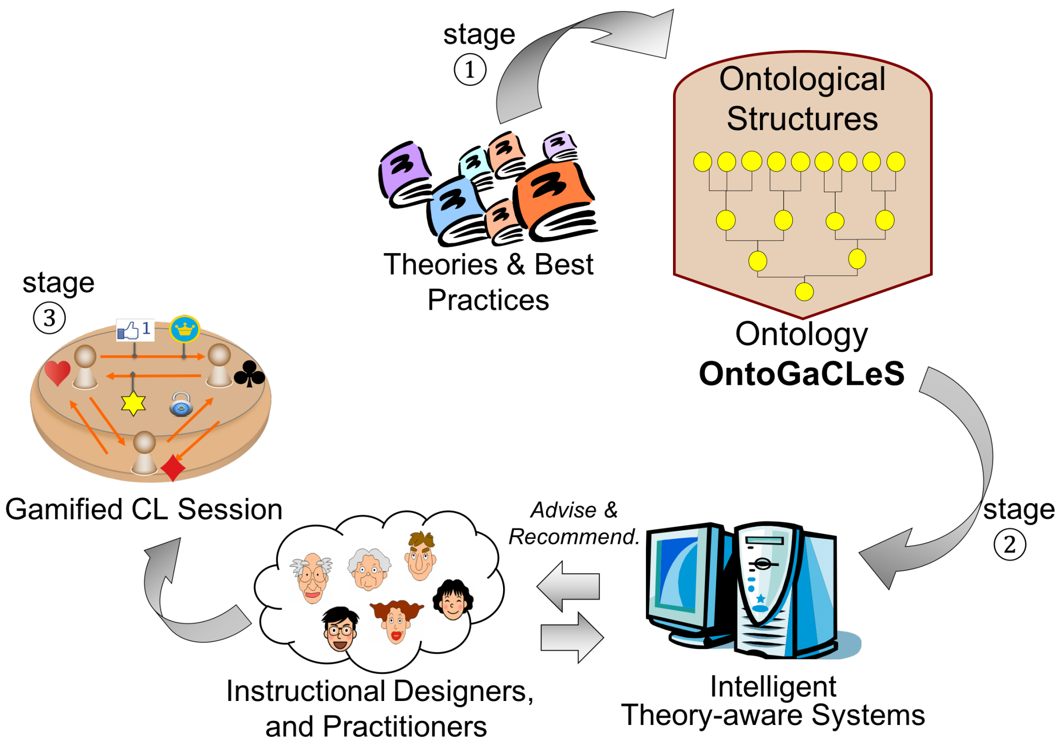
Therefore, the general research goal in this PhD thesis dissertation refers to the definition of an ontology to, from a philosophical perspective, systematically formalize the knowledge extracted from the best practices and theories related to gamification, and the definition of computer-based mechanisms that employ this ontology to deal with the motivation problem caused by the scripted collaboration in CL activities where the CSCL scripts are used as a method 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 the knowledge encoded in the ontology OntoGaCLeS be used by these mechanisms and procedures for dealing with the motivation problem caused by the scripted collaboration?

Regarding to 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 (Stage 3), the research questions answered by this dissertation are:

RQ4: What are the effects of ontology-based gamified CL sessions on the students' motivation and learning outcomes? and What are the effectiveness and efficiency of these sessions to deal with the motivation problem caused by the scripted collaboration?

The research objectives pursued to answer the research questions *RQ1* and *RQ2* are:

RO1: To review the scientific literature in order to identify the most relevant concepts from the theories and practices related to gamification that should be taking into account to deal with the motivation problem caused by the scripted collaboration, and how these concepts be applied in the gamification of CL scenarios; and

RO2: To define the necessary ontological structures to represent the concepts identified as relevant in the scientific literature of gamification to deal with the motivation problem caused by the scripted collaboration.

In order to answer the research question *RQ3*, the research objectives is:

RO3: To identify and define the computer-based mechanisms and procedures that must be implemented by intelligent-theory aware systems to give a helpful support in the gamification of CL scenarios, and how these mechanisms and procedure use the knowledge encoded in the ontology OntoGaCLeS for dealing with the motivation problem caused by the scripted collaboration.

The research objective pursued to answer the research question *RQ4* is:

RO4: to analyze the effects of ontology-based gamified CL sessions on the students' motivation and learning outcomes for the purpose of validating the ontology engineering approach to gamify CL scenarios in reference to the effectiveness and efficiency to deal with the motivation problem caused by the scripted collaboration.

It is out of scope in this dissertation to deal with the following objectives:

- To compare, validate or judge the best practices and theories related to gamification.

- To create, modify or extend the concepts described in the best practices and theories related to gamification.
- To create a generic and complete representation of all concepts described in the practices and theories related to gamification. The author of this thesis only concentrates on the formalization of the minimal necessary concepts from these practices and theories to deal with the motivation problem caused by the scripted collaboration.
- To validate the concepts and ontological structures formalized in the ontology OntoGaCLeS using semantic reasoner engines or formal methods based on logic and/or mathematics.

1.3 Research Methodology

As this PhD thesis dissertation is framed in the multidisciplinary field of CSCL with research questions and research objectives oriented to be answered and achieved by theoretical and empirical studies, a mixed research method needs to be employed to conduct this research. Following the research methodology framework proposed by Glass (1995), Glass, Vessey and Ramesh (2002), the mixed research method employed in this PhD thesis research consists in four iterative phases: informational, propositional, analytical and evaluation.

Informational phase: In this phase, the research problems and potential solutions were identified based on information gathered from the scientific literature and discussions with experts in fields of CSCL, gamification and ontology engineering. The results of this phase were an outline of the knowledge involved in this dissertation, the research questions, and the research objectives. The tasks carried out in this phase correspond to tasks extracted from the scientific (observing the world) and engineering (observing existing solutions) research methods. These tasks were:

- The search, review and analysis of scientific literature regarding to: CSCL, gamification and ontology engineering. This literature review was performed with emphasis in scripted collaboration, gamification of learning and instruction, and ontology-engineering applied to Artificial Intelligence in Education (AIED).
- The participation as member of the research group in Applied Computing in Education Laboratory (CAEd-Lab, *Laboratorio de Computação Applicada a Educação e Tecnologias Sociales Avançadas*) at the University of São Paulo. Particularly, the expertise field in CSCL and Ontologies of this research group has been very important and valuable to conduct the research and the literature reviews.
- The participation in several conferences and workshops related to the context and problem domain in which this dissertation is framed. These conferences and workshop, in chronological order, were: the III Escola de Ontologias UFAL-USP, 2014

(Workshop); the 20th International Conference on Collaboration and Technology, CRIWG, 2014 (Conference), the Summer School on Computers in Education, 2015 (Workshop); the XXVI Brazilian Symposium on Computers in Education, 2015 (Conference); the 6th Latin American School for Education, Cognitive and Neural Sciences, 2016 (Workshop); and the Higher Education for All: International Workshop on Social, Semantic, Adaptive and Gamification techniques and technologies for Distance Learning, 2017 (Workshop).

- The participation as visiting research at the Research Center for Service Science at the School of Knowledge Science in the Japan Advanced Institute of Science and Technology (JAIST) has also been significant for the informational phase. This research center is dedicated to study, design and implementation knowledge co-creation process in complex service systems. This research center focuses in the use of ontologies and ontology-engineering as the technology to develop and solve a broad variety of domains/tasks, and their research members have a long history working in the research field of Artificial Intelligence in Education. Particularly, the expertise of the Prof. Mitsuro Ikeda and Prof. Riichiro Mizoguchi were valuable and important for this phase due to their involvement in various research projects related to the modeling of knowledge for the students' learning growth, CL process, and instructional design.

Propositional phase: In this phase, solutions were proposed and formulated using the information gathered in the previous phase. As results of the propositional phase, constructors of necessary concepts to gamify CL scenarios were identified and proposed as ontological structures in the ontology OntoGaCLeS. Prototypes of computer-based mechanisms and procedures were also developed for gathering practitioner and user opinions as early feedback of these systems. The tasks carried out in this phase correspond to task extracted from the scientific (proposing theories or models) and engineering (proposing and developing solutions) research methods. These tasks were:

- The proposal of ontological structures in the ontology OntoGaCLeS to represent gamified CL scenarios and ontological models to personalize the gamification of CL scenarios based on player type models and need-based theories of motivation.
- The proposal of ontological structures in the ontology OntoGaCLeS to represent the application of persuasive game design models in gamified CL scenarios and ontological models to apply persuasive game strategies as a method for dealing with the motivation problem caused by the scripted collaboration.
- The proposal of a computer-based model to unify the modeling of the learners' growth process and the flow theory based on the principle of good balance between the perceived challenges and skills.

- The definition of a conceptual flow to gamify CL scenarios as a computer-based procedure to use the knowledge described in the ontology OntoGaCLeS, and the definition of a reference architecture based on this flow to build computer-based mechanisms that provide support in intelligent-theory aware systems for dealing with the motivation problem caused by the scripted collaboration.

Analytical phase: This phase consists into analyze and explore the solutions formulated in the propositional phase with the purpose to identify whether the proposed solutions are understandable, how them can be deployed into practice, what are the potential problems in understanding and using them, and wether there are any omissions or gaps in these solutions. The tasks carried out in this phase correspond to task extracted from the empirical (applying to case studies) and analytical (developing new solutions derived from the results obtained in the case studies) research methods. These tasks were:

- The formalization of an ontological model to personalize the gamification of CL scenarios based on the Dodecad player type model proposed by Marczewski (2015b), and the formalization of an ontological model to personalize the gamification of Cognitive Apprentice CL scenarios based on the Yee's player type model. These two formalizations were developed as case studies to validate in the evaluation phase the ontological structures proposed to systematically formalize ontological models to personalize the gamification of CL scenarios.
- The formalization of an ontological model to apply gamification as a persuasive technology in gamified Cognitive Apprenticeship scenarios employing the persuasive game design strategies defined in the Model-driven persuasive game proposed by Orji (2014).
- The implementation of a computer-based mechanism (as a proof of concept) in which the knowledge encoding in the ontology OntoGaCLeS is used for setting up the proper player roles and game elements for CL sessions.
- The development of an algorithm (as a proof of concept) to apply the principle of good balance between the perceived challenges and skills from the flow theory in the gamification of CL scenarios.
- The development of a computer-based mechanisms (as a proof of concept) to apply gamification as persuasive technology in the gamification of CL scenarios.

Evaluation phase: The focus of this phase is to conduct empirical tests and evaluations for the solutions formulated in the propositional phase and for the findings found in the analytical phase. In this phase, the empirical data gathered through the tests and evaluations aim to assess the contributions from different perspectives. The task carried out in this phase correspond to task from the empirical (validating the solutions) and analytical (analyzing the results obtained from empirical observations) research methods. These tasks were:

- The analytical evaluation of the ontological structures proposed to represent gamified CL scenarios and the ontological models to personalize the gamification of CL scenarios. This evaluation was carried out by publishing these ontological structures and the ontological models obtained from them in the analytical phase (the ontological model to personalize gamification in CL scenarios based on the Dodecad player type model, and the ontological model to personalize gamification in Cognitive Apprentice CL scenarios based on the Yee's player type model) as scientific articles in conferences and journals related to the fields of CSCL, and Artificial Intelligent in Education. These articles, in chronological order, were: "*Towards an Ontology for Gamifying Collaborative Learning Scenarios*" published in the 12$^{\text{th}}$ International Conference on Intelligent Tutoring Systems, ITS, 2014; "*An Ontology Engineering Approach to Gamify Collaborative Learning Scenarios*" published in the 20$^{\text{th}}$ International Conference on Collaboration and Technology, CRIWG, 2014; and "*Personalization of Gamification in Collaborative Learning Contexts using Ontologies*" published in the journal of IEEE Latin America Transactions, 2015. During the conferences important feedbacks to improve the ontological structures were obtained from informal discussions with the participants of the conferences who shared their expertise in the domain of CSCL and Artificial Intelligent in Education.

- The analytical evaluation of the ontological structures proposed to represent the application of persuasive game design models in gamified CL scenarios and the ontological models to apply persuasive game strategies as a method for dealing with the motivation problem caused by the scripted collaboration. This evaluation was carried out by publishing these ontological structures and the ontological models obtained from them in the analytical phase (the ontological model to apply gamification as a persuasive technology in gamified Cognitive Apprenticeship scenarios employing the persuasive game design strategies defined in the Model-driven persuasive game) as scientific articles scientific articles in conferences and journals related to the fields of CSCL, and Artificial Intelligent in Education. These articles, in chronological order, were: "*Steps Towards the Gamification of Collaborative Learning Scenarios Supported by Ontologies*" published in the 17$^{\text{th}}$ International Conference on Artificial Intelligence in Education, AIED, 2015; "*An Ontological Model to Apply Gamification as Persuasive Technology in Collaborative Learning Scenarios*" published in the 26$^{\text{th}}$ Brazilian Symposium of Informatics in Education, SBIE, 2015; "*Gamification of Collaborative Learning Scenarios: Structuring Persuasive Strategies Using Game Elements and Ontologies*" published in the 1$^{\text{st}}$ International Workshop of Social Computing in Digital Education, SOCIALEDU, 2015; and "*An Ontology Framework to Apply Gamification in CSCL Scenarios as Persuasive Technology*" published in the Brazilian Journal of Computers in Education, 2016. During the conferences important feedbacks to improve the ontological structures were obtained from informal discussions with the participants of the conferences who shared their expertise in the domain of CSCL and Artificial Intelligent in Education.

- The conduction of a pilot empirical study in which, prior to carry out the full-scale empirical studies, the activities, methods, instruments and activities that have been used in the full-scale studies were evaluated to adjust and improve the full-scale study design. This empirical study has been conducted to assess the effectiveness of *the ontological engineering approach to gamify CL scenarios* for dealing with the motivation problem caused by the scripted collaboration. Such effectiveness is measured by comparing the effect of the ontology-based CL sessions obtained by the approach against the effect of non-gamified CL sessions on the participants' intrinsic motivation and learning outcomes, and the percentage of participation by groups. This empirical study was conducted with undergraduate computer science students at the university of São Paulo during the second semester of 2016 in the course of Laboratory of Introduction to Computer Science, and for a CL activity related to the topic of loop structures. In such CL activity, the ontology-based gamified sessions and non-gamified CL sessions have been instantiated using a CSCL script inspired by the cognitive apprenticeship theory as the method to orchestrate and structure the collaboration among the students.
- The conduction of a full-scale empirical to evaluate the effectiveness of *the ontological engineering approach to gamify CL scenarios*. This effectiveness has been measured by comparing the effects of ontology-based gamified CL sessions against the effects of non-gamified CL sessions on the participants' intrinsic motivation and learning outcomes. This study was carried out in the course of introduction to computer science with undergraduate computer engineering students at the university of São Paulo during the first semester of 2017. The CL activity in which these CL sessions have been instantiated was related to the topic of condition structures using a CSCL script based on the cognitive apprentice theory to orchestrate and structure the collaboration among the participants.
- The conduction of a full-scale empirical study to also evaluate the effectiveness of *the ontological engineering approach to gamify CL scenarios*. However, in this empirical study, the effects of ontology-based gamified CL sessions against the effect of non-gamified CL sessions were compared on the participants' level of motivation instead to compare these effects on the participants' intrinsic motivation. This empirical study was carried out during the first semester of 2017 in the course of Introduction to Computer Science at the university of São Paulo with undergraduate computer engineering students. In this context, a CSCL script inspired by the cognitive apprentice theory was used to structure and orchestrate the collaboration among the students a CL activity related to the the topic of loop structures.
- The conduction of a full-scale empirical study to evaluate the efficiency of *the onto-*

logical engineering approach to gamify CL scenarios for dealing with the motivation problem caused by the scripted collaboration. Such efficiency was measured by comparing the effects on the participants intrinsic motivation, level of motivation, and learning outcomes caused by ontology-based CL sessions against the effects caused by CL sessions that have been gamified without using the support given by the ontology OntoGaCLeS. This empirical study was carried out in the course of Introduction to Computer Science at the university of São Paulo during the first semester of 2017. The undergraduate computer engineering students signed up in this course participated in a CL activity related to the topic of recursion in which the collaboration among the students was orchestrated and structured by a CSCL script inspired by the cognitive apprentice theory.

1.4 Thesis Statement and Claimed Contributions

The thesis statement of this PhD thesis dissertation is that:

"*For CL activities where the CSCL scripts are used as a method to orchestrate and structure the collaboration among the participants, the gamification of CL scenarios using the support given by the ontology OntoGaCLeS constitutes an effective and efficient solution to deal with the motivation problem caused by the scripted collaboration because this ontology encodes the necessary theoretical knowledge related to theories and best practices of gamification to perform this task*."

The claimed contributions are:

1. The identification of most relevant concepts from the theories and practices related to gamification that should be taking into account to deal with the motivation problem caused by the scripted collaboration (RO1).

2. Ontological structures that represent the concepts identified as relevant in the theories and practices related to gamification for dealing with the motivation problem caused by the scripted collaboration (RO2).

    a) A set of ontological structures to represent gamified CL scenarios and ontological models to personalize the gamification of CL scenarios based on player types models and need-based theories of motivation.

    b) A set of ontological structures to apply persuasive game design models in gamified CL scenarios and ontological models to apply persuasive game strategies as a method for dealing with the motivation problem caused by the scripted collaboration.

c) A unify modeling of learners' growth process and flow theory as a computer-based model to apply the principle of good balance between the perceived challenges and skills for gamified CL scenarios.

3. A conceptual flow to gamify CL scenarios using the knowledge described in the ontology OntoGaCLeS, and a reference architecture based on this flow to build computer-based mechanisms that provide support in intelligent-theory aware systems for dealing with the motivation problem caused by the scripted collaboration (RO3).

4. An empirical evaluation of *the ontological engineering approach to gamify CL scenarios* in which, to validate the effectiveness and efficiency of this approach for dealing with the motivation problem caused by the scripted collaboration, the effects of ontology-based gamified CL sessions on students' intrinsic motivation, level of motivation and learning outcomes are compared against the effects caused by the non-gamified CL sessions and CL sessions that have been gamified without using the support given by the ontology OntoGaCLeS (RO4).

1.5 Structure of the Dissertation

This PhD thesis dissertation is structured in eight chapters:

Chapter 1: *Introduction*

Chapter 2: *General Background and Fundamental Concepts* contains the background related to the context and research problem addressed in this dissertation. An overview related to the fields of CSCL and scripted collaboration, gamification and ontology engineering are presented in the chapter. The motivation problem caused by the scripted collaboration, and the current approaches to deal with this problem are also detailed in the chapter. The concepts that were identified as relevant in the theories and practices of gamification and their difficulties to apply it in CL scenarios for dealing with the motivation problem caused by the scripted collaboration are presented in the chapter.

Chapter 3: *Ontological Structure to Personalize the Gamification in CL Scenarios* describes the ontological structures, that have been proposed by the author of this thesis, and that have been formalized in the ontology OntoGaCLeS, to represent gamified CL scenarios and ontological models to personalize the gamification in CL scenarios based on player types models and need-based theories of motivation. The chapter also shows the procedure followed to build an ontological model ontological model to personalize the gamification of CL scenarios based on the Dodecad player type model.

Chapter 4: *Ontological Structures of Persuasive Game Design in CL Scenarios* describes the ontological structures proposed by the author of this thesis to apply persuasive game design models in gamified CL scenarios and to represent ontological models to apply persuasive game strategies as a method for dealing with the motivation problem caused by the scripted collaboration. The chapter also describes the procedure to formalize an ontological model in which gamification is applied as persuasive technology for gamified Cognitive Apprenticeship scenarios employing the persuasive game design strategies defined in the Model-driven persuasive game proposed by Orji (2014).

Chapter 5: *A Unify Modeling of Learners' Growth Process and Flow Theory* presents the computer-based model proposed by the author of this thesis to unify the modeling of the learners' growth process and the flow theory based on the principle of good balance between the perceived challenges and skills. This model has been used in the gamification of CL scenarios to define the rewards to be promised and given to maintain the learner's flow state in the CL process.

Chapter 6: *Computer-based Mechanisms and Procedures to Gamify CL Scenarios* describes the flow proposed by the author of this thesis to use the knowledge described in the ontology OntoGaCLeS to gamify CL scenarios. The reference architecture based on this flow by which computer-based mechanisms could be built in intelligent-theory aware systems to provide support in the gamification of CL scenarios for dealing with the motivation problem caused by the scripted collaboration is presented in the chapter. The chapter also describes the computer-based mechanisms that has been developed by the author of this thesis using the reference architecture to conduct the evaluation of the ontological engineering approach to gamify CL scenarios.

Chapter 7: *Evaluation of the Ontological Engineering Approach to Gamify CL Scenarios* presents the empirical studies that have been carried out in real situations to validate the effectiveness and efficiency of this approach to deal with the motivation problem caused by the scripted collaboration.

Chapter 8: *Conclusions and Future Work* summarizes the contributions of this PhD thesis dissertation, and the chapter also discusses possible future research directions.

CHAPTER

2

GENERAL BACKGROUND AND FUNDAMENTAL CONCEPTS

CHAPTER

3

ONTOLOGICAL STRUCTURES TO PERSONALIZE THE GAMIFICATION IN COLLABORATIVE LEARNING SCENARIOS

This chapter presents the formalization of ontological structures that have been proposed by the author of this thesis dissertation to represent gamified CL scenarios. These ontological structures allow us to systematically represent knowledge extracted from player types models and needs-based theories of motivation to deal with the motivation problem caused by the scripted collaboration. This knowledge corresponds to concepts identified by the author of this thesis as relevant to solve the context-dependency related to the individual user characteristics, so that the ontological structures described in this chapter are also used to represent ontological models to personalize the gamification in CL scenarios based on player types models and need-based theories of motivation. The ontological structures to represent gamified CL scenarios have been developed as an extension of ontological structures proposed to represent CL scenarios in the CL ontology, hence the chapter starts with an overview of the CL ontology (section 3.1). The ontological structures that have been formalized in the ***Onto****logy to* ***Ga****mify* ***C****ollaborative* ***Le****arning* ***S****cenarios* - **OntoGaCLeS** to represent gamified CL scenarios based on the knowledge extracted from player types models and needs-based theories of motivation are presented in section 3.2. To demonstrate the usefulness of this formalization, and then to validate the ontological structures as a formal representation of ontological models to personalize the gamification in CL scenarios, section 3.3 shows the procedure followed to build an ontological model to personalize the gamification of CL scenarios based on the Dodecad player type models (MARCZEWSKI, 2015b). Finally, section 3.4 presents the concluding remarks of this chapter.

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

- "*Towards an Ontology for Gamifying Collaborative Learning Scenarios*" published in the

12th International Conference on Intelligent Tutoring Systems, ITS 2014, held in Honolulu, HI, USA (CHALLCO *et al.*, 2014).

- "*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).

- "*Personalization of Gamification in Collaborative Learning Contexts using Ontologies*" published as Volume 13, Issue 6, in the journal of IEEE Latin America Transactions, 2015 (CHALLCO *et al.*, 2015).

3.1 Overview of the Collaborative Learning Ontology

The CL ontology has been developed for a long time by the contributions of many researchers. Initially, the CL ontology was conceived to support the opportunistic group formation (IKEDA; GO; MIZOGUCHI, 1997), so that, to identify situations in which an individual shifting from individual learning mode to CL mode, the CL ontology has been formalized the agreement in the negotiation process for group formation as ontological structures that describe individual and group learning goals. Employing this formalization, intelligent agents have been developed to help students to find group members for establishing group learning activities in which they should participate. These agents check the individual and group learning goals, and then they initiate a negotiation process to establish an agreement of whom participate in group learning activities. This first version of the CL ontology has been demonstrated to be useful in the development of agent-based systems that provide helpful support for the group formation (INABA *et al.*, 2001; SUPNITHI *et al.*, 1999).

In order to provide theoretical and pedagogical justification for the group formation, the first version of the CL ontology has been extended to represent CL scenario that compliant with instructional and learning theories (INABA; MIZOGUCHI, 2004; ISOTANI *et al.*, 2013). In this extension, concepts, such as interaction patterns, group goals, individual goals, CL roles and so on, have been formalized from different instructional/learning theories, so that, in addition to support the group formation (ISOTANI; MIZOGUCHI, 2008), the ontological structures to represent CL scenarios have been successfully applied in: the modeling of learners' development (INABA; IKEDA; MIZOGUCHI, 2003) the interaction analysis (INABA *et al.*, 2002), and the design of CL process (ISOTANI *et al.*, 2013).

Figure 2 shows the terms, concepts and relations defined in the CL ontology. These concepts are defined as follows as:

I-goal is the individual learning goal that represents what the participant in focus (*I*) is expected to acquire, and it is described as a change in his/her learning stage.

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

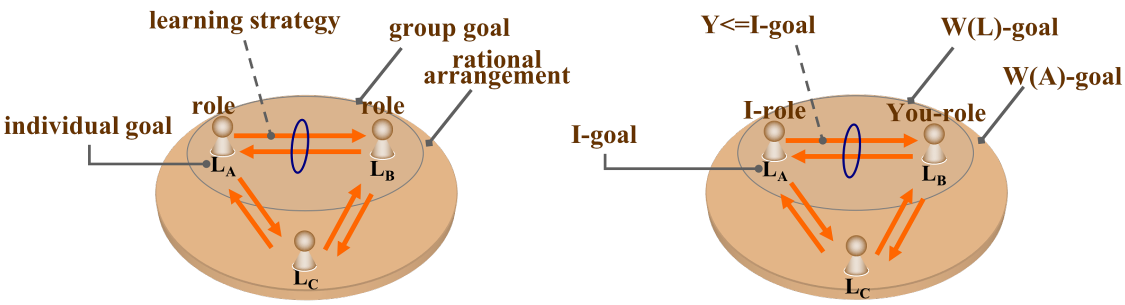
You-role is the CL role played by the participant (*You*) who is interacting with the participant in focus (*I*).

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 2 – Concepts, terms and relations defined in the CL Ontology

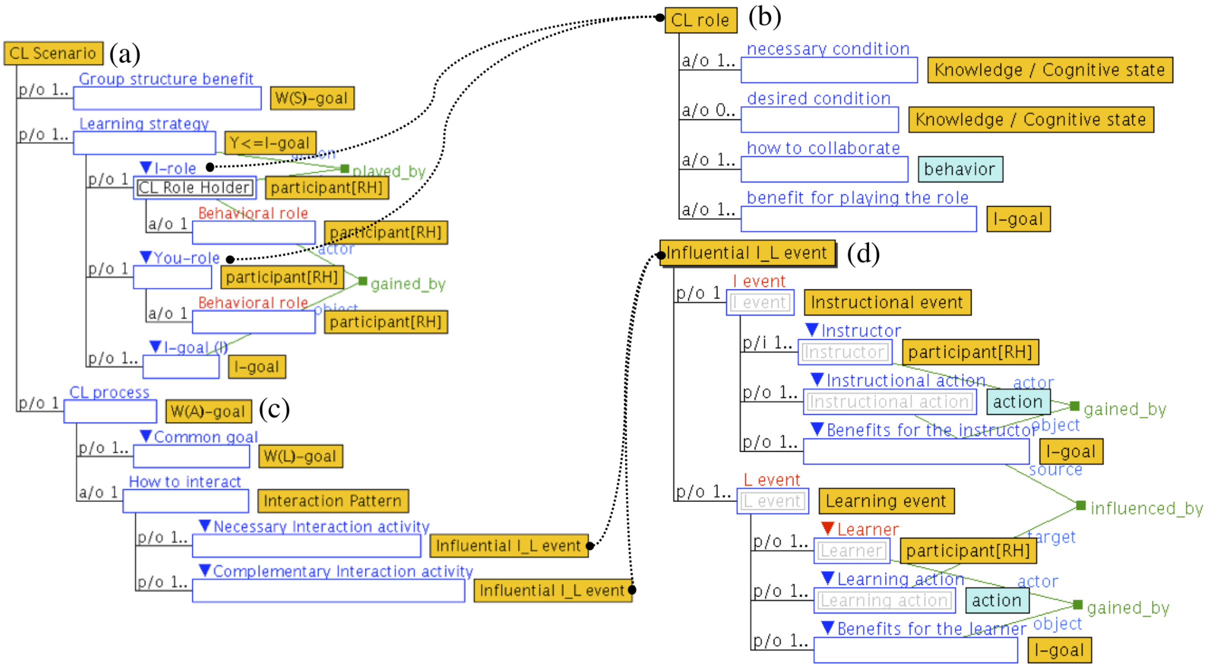


Source: Isotani (2009).

To express the relationship of concepts described above, the CL Ontology employs the ontological structures shown in Figure 3 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 3 – 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*.

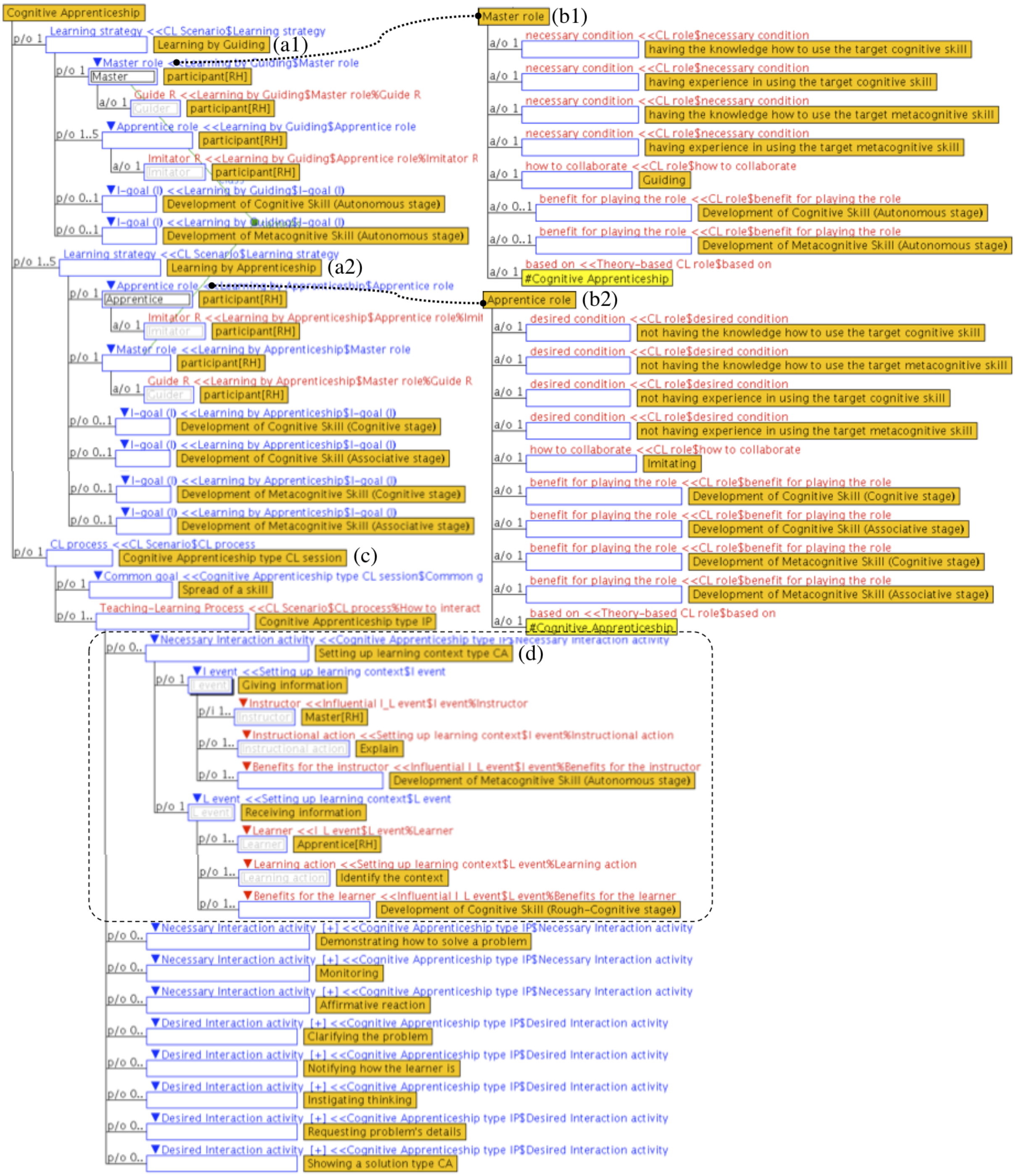
(c) The **CL process** is the *rational arrangement of group activity* (*W(A)-goal*) whereby the common and individual learning goals are achieved by the group members. This arrangement is represented by the *common learning goals* (*W(L)-goal*) as result of the negotiation process in the group formation, 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 3 are used to describe CL scenarios that compliant with instructional and learning theories. To illustrate this, Figure 4 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 4 (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 4 – Ontological structures to represent a CL scenario based on the cognitive apprenticeship theory

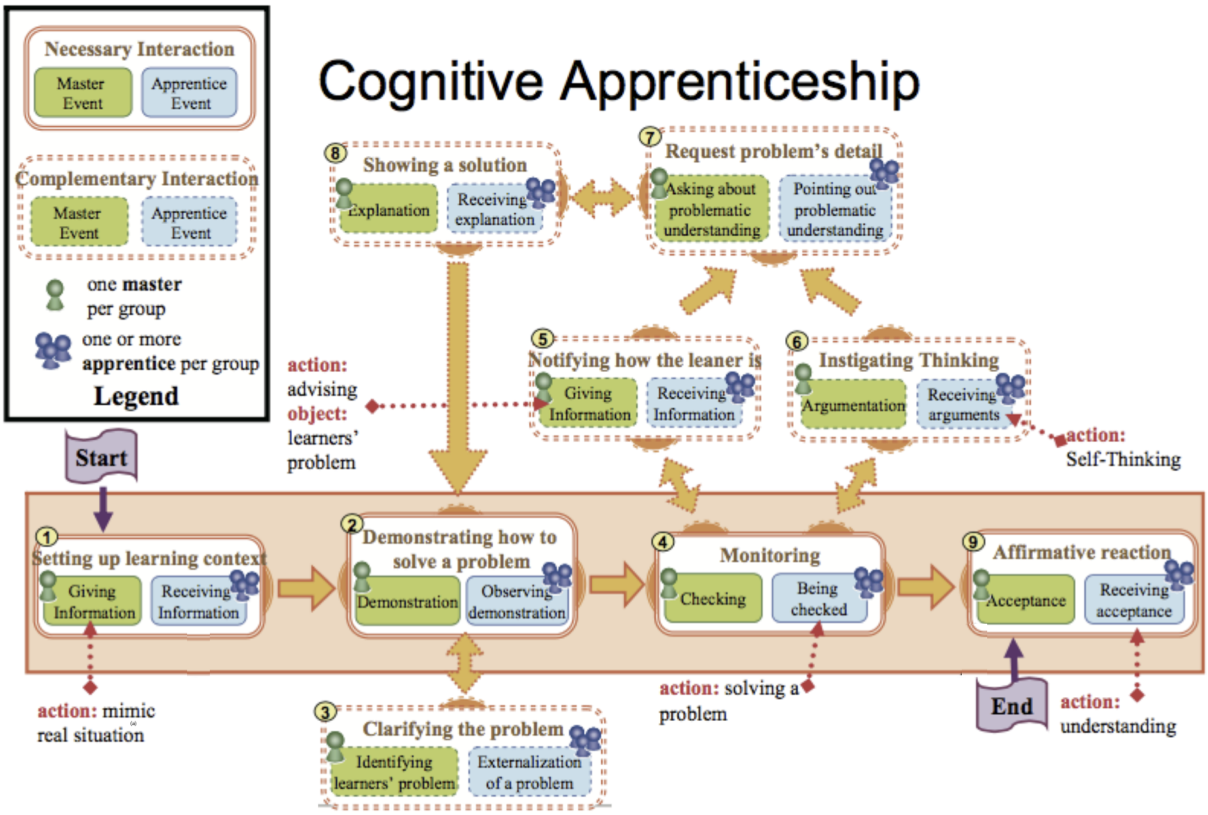


Source: Elaborated by the author.

role. Therefore, there is not necessary conditions in the ontological structure shown in Figure 4 (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 4 (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 5.

Figure 5 – Necessary and complementary interactions defined by the sequencing mechanism of a CSCL script inspired by the cognitive apprenticeship theory



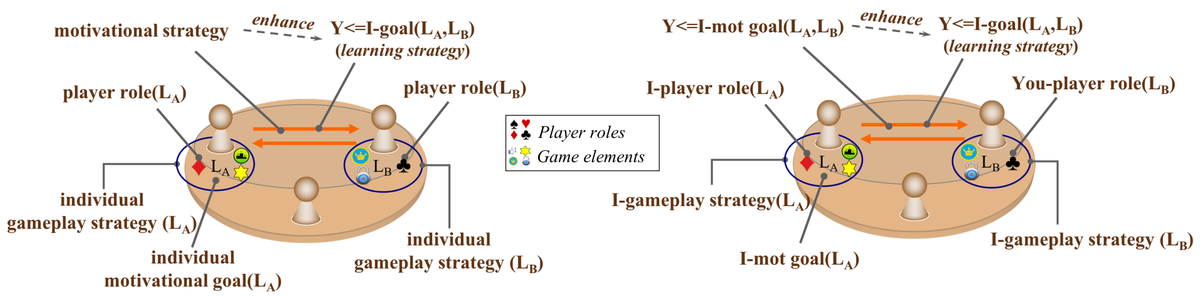
Source: Adapted from Isotani (2009).

The necessary and desired interactions defined by the sequencing mechanism shown in Figure 5 are formalized as *Influential I_L event* in the *Teaching-Learning Process* of *Cognitive Apprenticeship type CL session* shown in Figure 4 (c). The ontological structure to represent the interaction “*Setting up learning context type CA*” is shown in detail in Figure 4 (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 6 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 6 – 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.

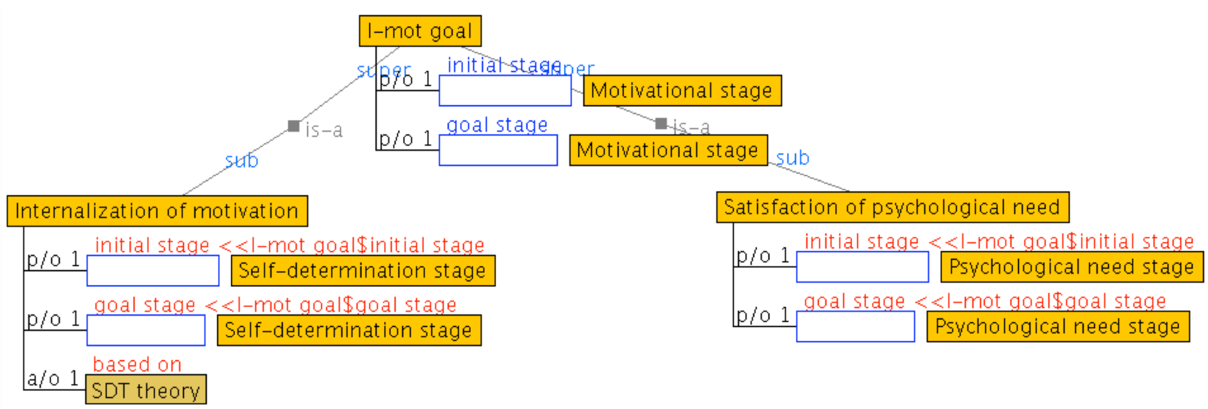
In the following subsections, the formalization of concepts, terms and relations briefly introduced here are detailed.

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 7 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 7 – 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)



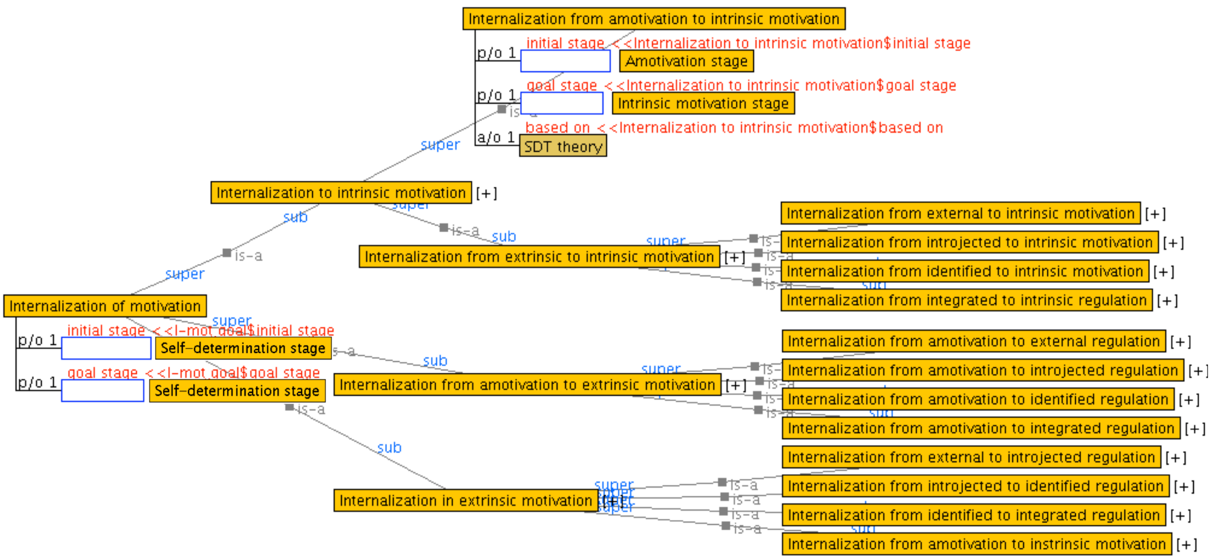
Source: Elaborated by the author.

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 7 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).

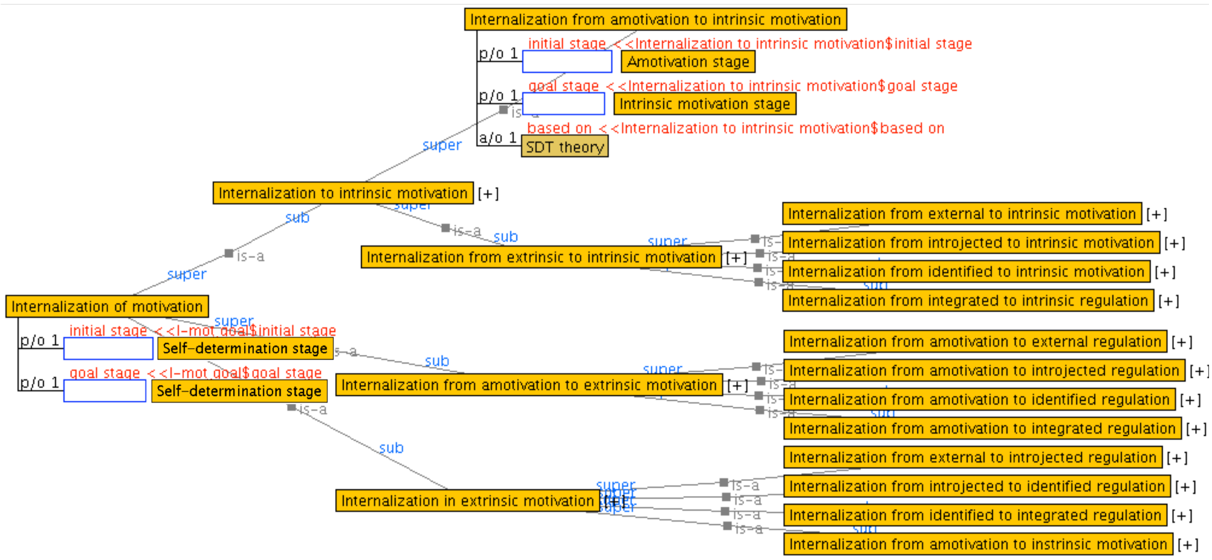
Figure 8 – Ontological structures to represent "*Satisfaction of psychological need*." At the top right, the ontological structure to represent "*Satisfaction of autonomy*."



Source: Elaborated by the author.

Figure 8 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 8, 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 **??**.

Figure 9 – 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 9 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 9 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 **??**.

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, 2006), 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 10. 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 **??**, 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.

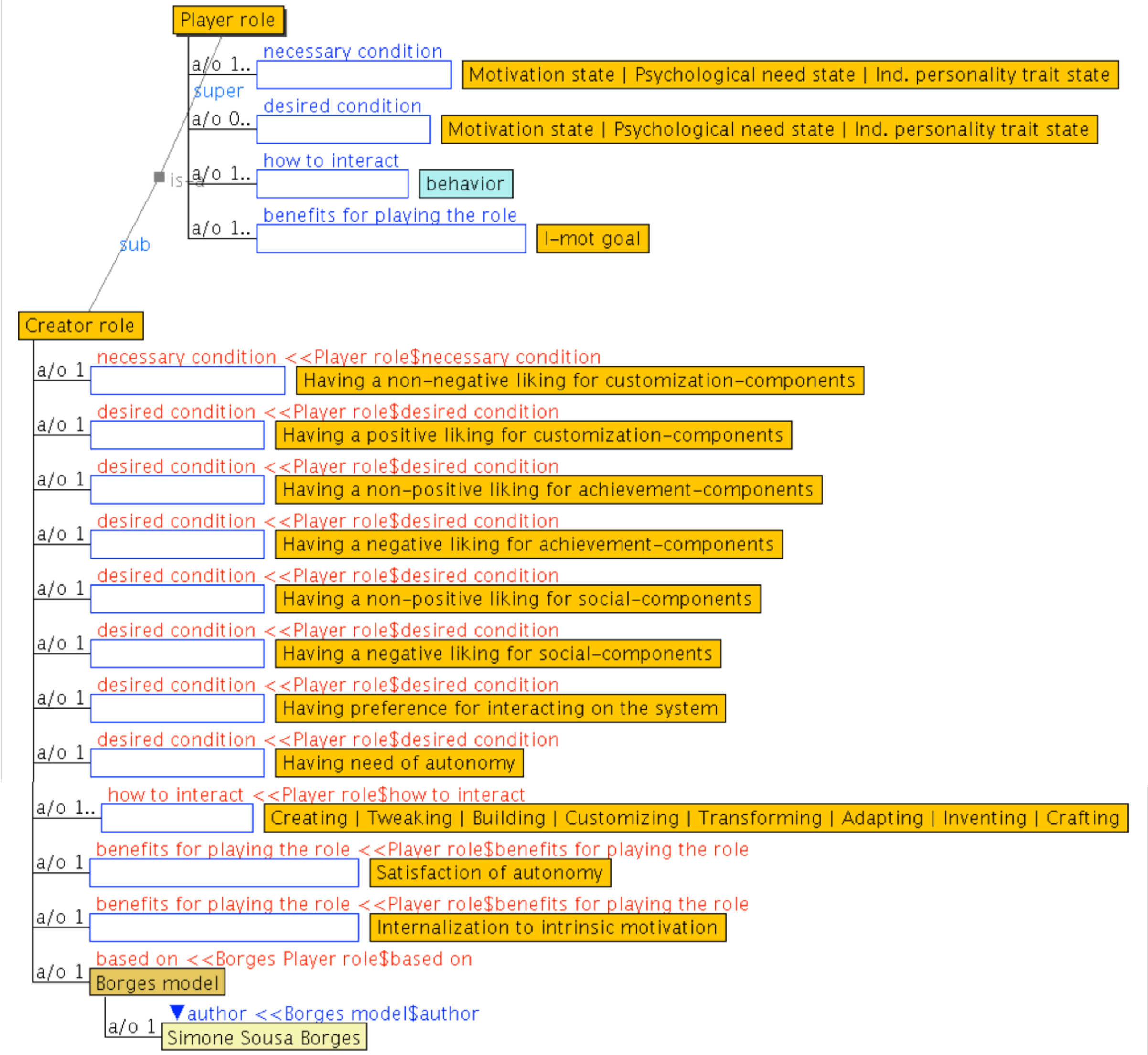
- The *psychological need state* represents the current psychological need of a person in which the states for each one of the psychological needs are formalized through the representation of pair states: "*Having need of $1*" and "*Not having need of $1*" in which "*$1*" is replaced by the name of the 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, 2006).

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 10 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 10, 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

Figure 10 – 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.

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 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 **??**.

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.

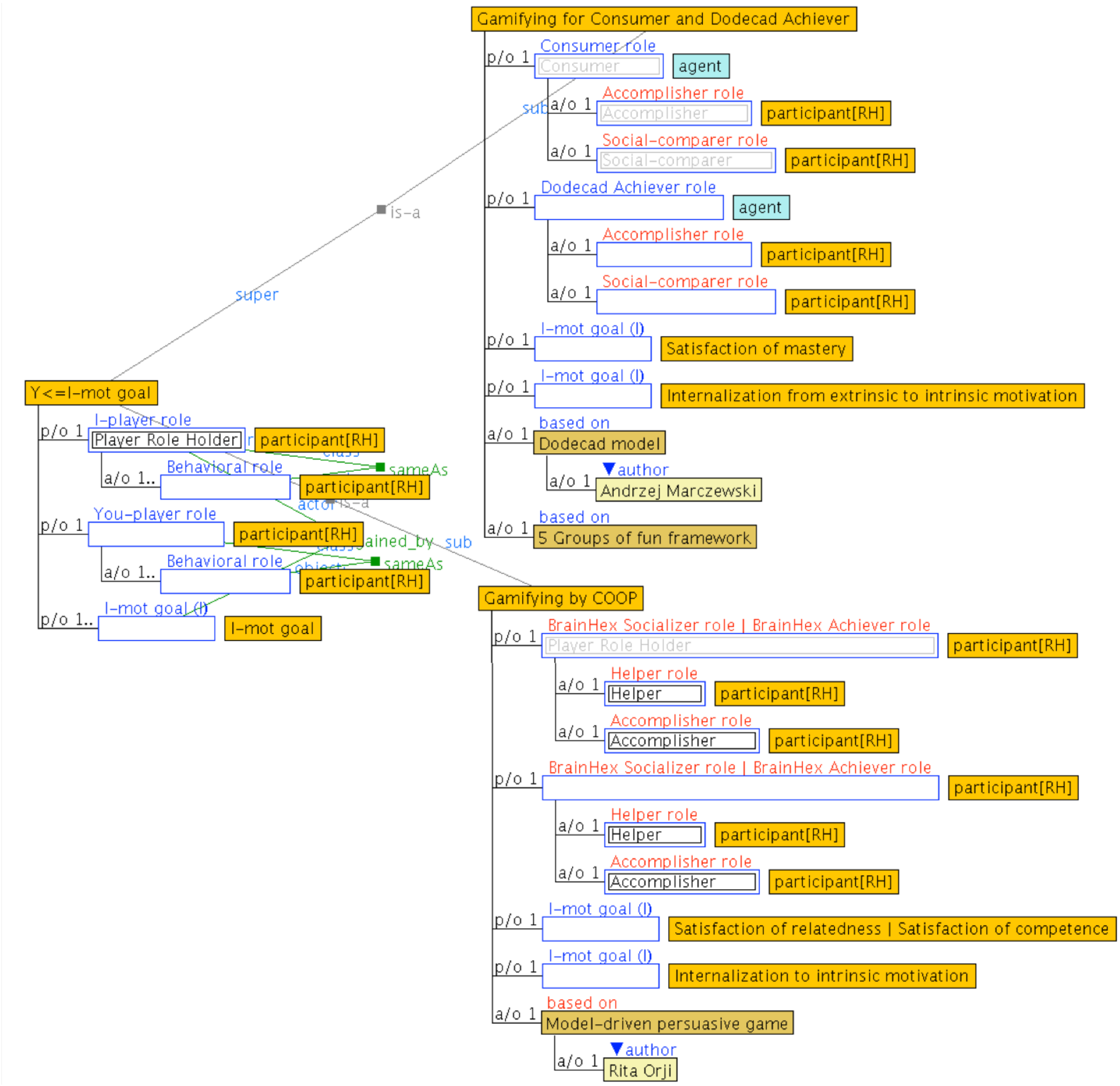
The ontological structure shown in Figure 11 has been proposed by the author of this PhD thesis dissertation to represent the formalization of individual motivational strategies whose guidelines are extracted from gamification models or game design models. According to this structure, an *individual 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 11 – 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 11 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 11 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 11, 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*).

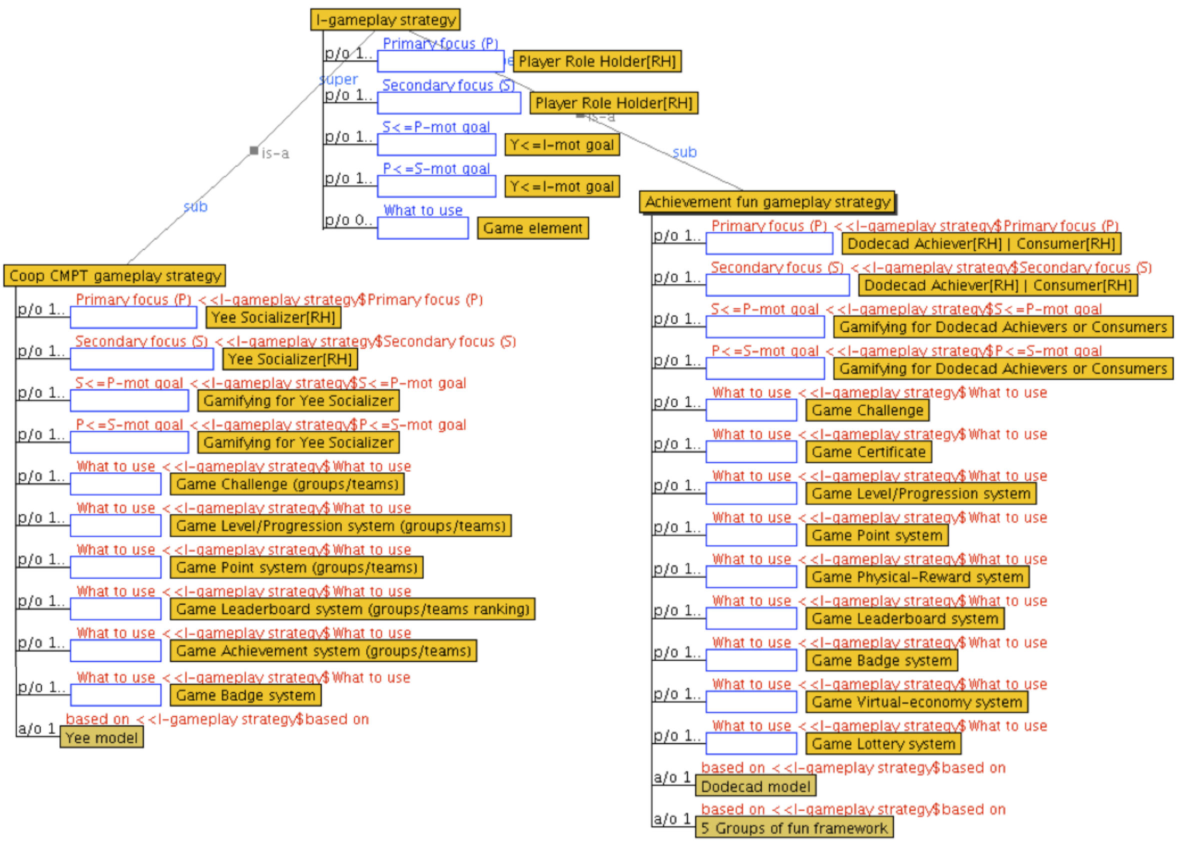
The individual motivational strategies based on gamification models currently defined in the ontology OntoGaCLeS, their player roles, their behavioral roles, and their individual motivational goals are detailed in **??**.

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;

G"OBEL, 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 12.

Figure 12 – 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).

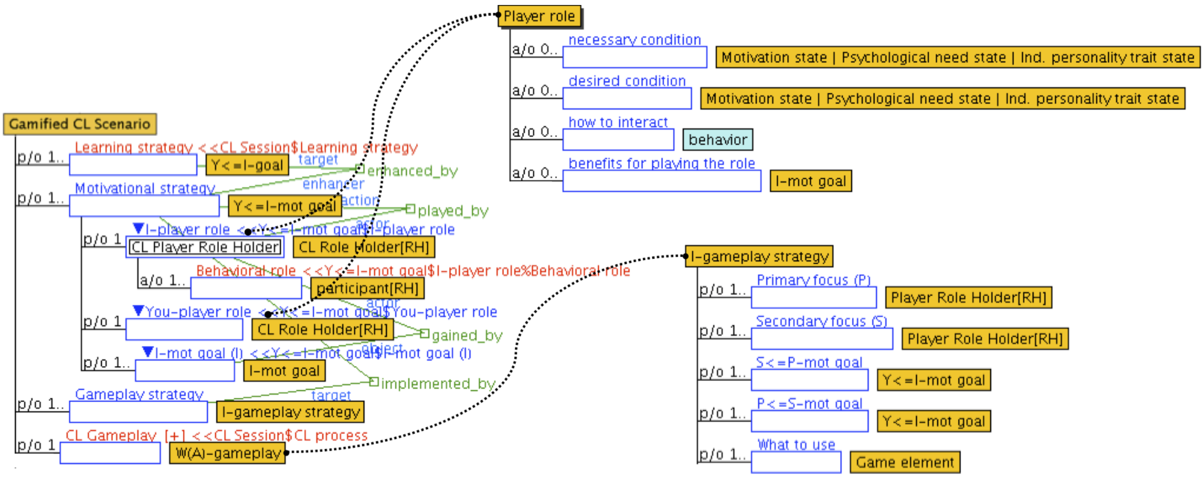
What to use indicates the game elements that are needed to carry out the individual gameplay strategy. Thus, the game elements defined in this attribute are the ones that are used to process the interactions of participants who are in the primary focus (P).

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 12 shows two examples of this formalization in which the guidelines described in the Yee's model (YEE, 2006) 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 3) 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 13.

Figure 13 – 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 13), 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*).

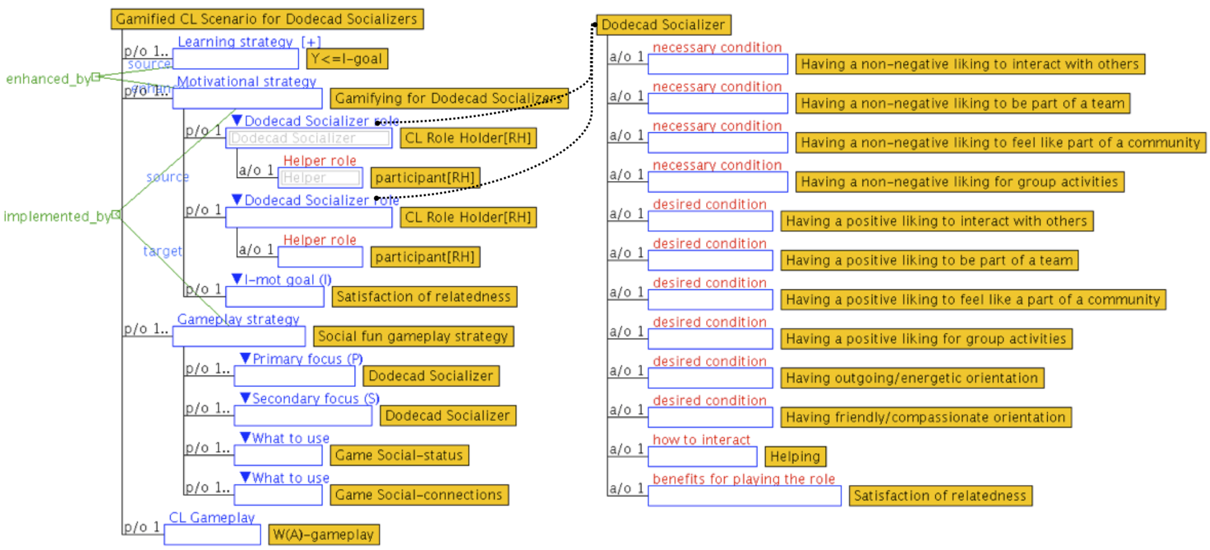
To illustrate the use of the ontological structures proposed in Figure 13, a gamified CL scenario for participant who plays the Dodecad Socializers has been formalized as shown in Figure 14, where the learning strategies (*Y<=I-goal*) of participants are *enhanced by* the individual motivational strategy "*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 14 – 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 13. 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. Table 1 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.

Table 1 – 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)

Table 1 – *(continued)*

	Peer-Tutor (explaining)	**Peer-Tutee** (passive learning)
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)

Step (2): Identifying Restrictions and Elements of Motivational Strategies

To identify the restrictions and elements of individual motivational strategies (*Y<=I-mot goal*), guidelines for the pairs of player roles identified in the step (1) are crossed. These guidelines are extracted from the player type models for the building of ontological models to personalize the gamification in CL scenarios. When these guidelines related to a pair of player roles are crossed, counterproductive behaviors are avoided to not interfere with the expected benefits that can be achieved by the participants playing these roles and performing these behaviors. The expected benefits are expressed as individual motivational goals (*I-mot goals*) based on interpretation of these benefits using need-based theories of motivation.

Table 2 shows the result obtained in this step for the definition of individual motivational strategies in the ontological model to personalize the gamification in Peer-tutoring CL scenarios. The rows indicate the player roles (*I-Player role*) for the participant in focus (*I*), and the columns indicate the player roles (*You-Player role*) for the participant (*You*) who interacts with the participant in focus (*I*). The individual gameplay strategies and their elements are indicated in the crossed cells. These strategies were defined from common guidelines for each pair of player roles. Thus, an individual gameplay strategy has been formalized in the ontological model when there are common expected behaviors indicated in the guidelines of player roles "*I-Player role*" and "*You-Player role*."

Table 2 – Individual motivational strategies identified for the building of an ontological model to personalize the gamification in Peer-tutoring scenarios

	Achiever (*accomplishing, comparing*)	**Socializer** (*helping*)	**Philanthropist** (*giving, helping, sharing*)	**Consumer** (*accomplishing, comparing*)	**Networker** (*helping*)	**Self-seeker** (*giving, helping, sharing*)
Achiever (*accomplishing, comparing*)	*Gamifying for Dodecad Achievers* • Satisfaction of mastery			*Gamifying for Dodecad Achievers and Consumer* • Satisfaction of mastery • Internalization from extrinsic to intrinsic motivation		
Socializer (*helping*)		*Gamifying for Dodecad Socializers* • Satisfaction of relatedness			*Gamifying for Dodecad Socializer and Networker* • Satisfaction of relatedness • Internalization from extrinsic to intrinsic motivation	
Philanthropist (*giving, helping, sharing*)			*Gamifying for Philanthropists* • Satisfaction of purpose			*Gamifying for Philanthropist and Self-seeker* • Satisfaction of purpose • Internalization from extrinsic to intrinsic motivation
Consumer (*accomplishing, comparing*)	*Gamifying for Consumer and Dodecad Achiever* • Satisfaction of mastery • Internalization from extrinsic to intrinsic motivation			*Gamifying for Consumers* • Satisfaction of mastery		

Table 2 – *(continued)*

	Achiever (*accomplishing, comparing*)	**Socializer** (*helping*)	**Philanthropist** (*giving, helping, sharing*)	**Consumer** (*accomplishing, comparing*)	**Networker** (*helping*)	**Self-seeker** (*giving, helping, sharing*)
Networker (*helping*)		*Gamifying for Networker and Dodecad Socializer* • Satisfaction of relatedness • Internalization from extrinsic to intrinsic motivation			*Gamifying for Networkers* • Satisfaction of relatedness	
Self-seeker (*giving, helping, sharing*)			*Gamifying for Self-seeker and Philanthropist* • Satisfaction of purpose • Internalization from extrinsic to intrinsic motivation			*Gamifying for Philanthropists* • Satisfaction of purpose

To illustrate the identification of restrictions and elements in the individual motivational strategy (*Y<=I-mot goal*), let us see the "*Gamifying for Dodecad Achiever and Conqueror*" indicated in Table 2, this strategy was identified from the guidelines of Dodecad model in which the behaviors of *accomplishing* and *comparing* are indicated as adequate to motivate achievers and consumers. In this case, the expected benefits to accomplish a goal, and then, compare it against the accomplishments of others is enjoyable for achievers. This benefit is represented as the individual motivational goal "*Satisfaction of mastery*" (*I-mot goal*) based on the Dan Pink motivation theory (PINK, 2011). According to this theory, mastery is a inherit human need that love to get better at stuff enjoying satisfaction from personal achievement and progress.

Step (3): Defining Individual Gameplay Strategies

Individual gameplay strategies (*I-gameplay strategy*) are inferred from the individual motivational strategies (*Y<=I-mot goal*) identified in the step (2). Game elements are defined to support the behaviors indicated in the guidelines of individual motivational strategies, and so obtain the expected benefits indicated as individual motivational goal. Table 3 shows the results of this step for the ontological model to personalize the gamification in Peer-tutoring scenarios.

Table 3 – Individual gameplay strategies to gamify Peer-tutoring scenarios

Achievement fun	**Social fun**	**Facilitated-personal fun**
Primary focus (P): • Gamifying for Dodecad Achiever • Gamifying for Consumer Secondary focus (S): • Gamifying for Consumer • Gamifying for Dodecad Achiever	Primary focus (P): • Gamifying for Dodecad Socializer • Gamifying for Networker Secondary focus (S): • Gamifying for Networker • Gamifying for Dodecad Socializer	Primary focus (P): • Gamifying for Philanthropists • Gamifying for Self-seekers Secondary focus (S): • Gamifying for Self-seekers • Gamifying for Philanthropists
What to use: • Challenges • Certificates • Levels/progression system • Point system (*levels/progression*) • Physical-reward system (*certificates*) • Leaderboard system (*levels/progression*) • Badge system (*level/progression*) • Virtual-economy system • Lottery system	What to use: • Social-status • Point system (*social status*) • Physical-reward system (*social status*) • Leaderboard system (*social status*) • Badge system (*social status*) • Virtual-economy system • Lottery system	What to use: • Meaning/purpose • Access system • Collect/trade system • Gifting/sharing system • Point system (*meaning/purpose*) • Physical-reward system (*meaning/purpose*) • Leaderboard system (*meaning/purpose*) • Badge system (*meaning/purpose*) • Virtual economy system • Lottery system

The individual gameplay strategies indicated in the Table 3 are:

- *Achievement fun gameplay strategy*: is an individual motivational strategy in which the system recognizes achievements through game challenges, certificates and level/progression. To satisfy the mastery need, the system must try to produce in the participants the feel that they are achieving something by performing the interactions indicated by the Peer-tutoring scripts. Thus, the system would use a point system to indicate the levels/progression in the CSCL script, and when the CL scenario is completed as a game challenge, a certificate would be given by a physical-reward system. The leaderboard system would indicate the level/progression of the script. Badges would be obtained by the participants at the end of CL scenario according to the level/progression in the script. Finally, virtual-economy and lottery systems would establish the relation between the levels/progression of the script and the points, ranking in the leaderboard and badges.

- *Social fun gameplay strategy*: is an individual motivational strategy in which social status is used to support the feeling of relatedness. In this sense, the system should provide some form of social network/group to indicate and/or create group/collective game elements. Thus, the system would use a points system with a social status system to indicate points gathered by the participant as group. When the CL scenario is completed, the system would give a physical reward for the groups. A leaderboard would provide rankings by groups to indicate the social status of groups. Badges for groups with a social status would be given by the system to groups when the CL scenario is completed. Finally, virtual-economy and lottery systems would establish the relation between the social status of groups in CL scenarios, and the points, physical-rewards, leaderboards, and badges.

- *Facilitated-personal fun gameplay strategy*: is an individual motivational strategy in which the excitement from changing the system satisfy the need of purpose. This satisfaction comes from collection and trading valuable things. So when participants help to others, game elements are collected to be converted into something that has a meaningful value. Thus, meaning/purpose should be given to game elements such as points, physical-rewards, leaderboards, and badges, so that the system provides a collect/trade system to change these element for gifting and/or sharable elements (such as elements to customize the avatars, elements to change part of the system).

Employing the information of Table 3, twelve ontological structures to represent gamified Peer-tutoring scenarios have been formalized in the ontology OntoGaCLeS to define the model to personalize the gamification in Peer-tutoring scenarios based on the Dodecad model (MARCZEWSKI, 2015b). These structures in the ontological model are: *Gamified Peer Tutoring Scenario for Achievers*, *Gamified Peer Tutoring Scenario for Achiever/Consumer*, *Gamified Peer Tutoring Scenario for Consumer/Achiever*, *Gamified Peer Tutoring Scenario for Consumers*, *Gamified Peer Tutoring Scenario for Socializers*, *Gamified Peer Tutoring Scenario* *for Socializer/Networker*, *Gamified Peer Tutoring Scenario for Networker/Socializer*, *Gamified 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 15 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*.

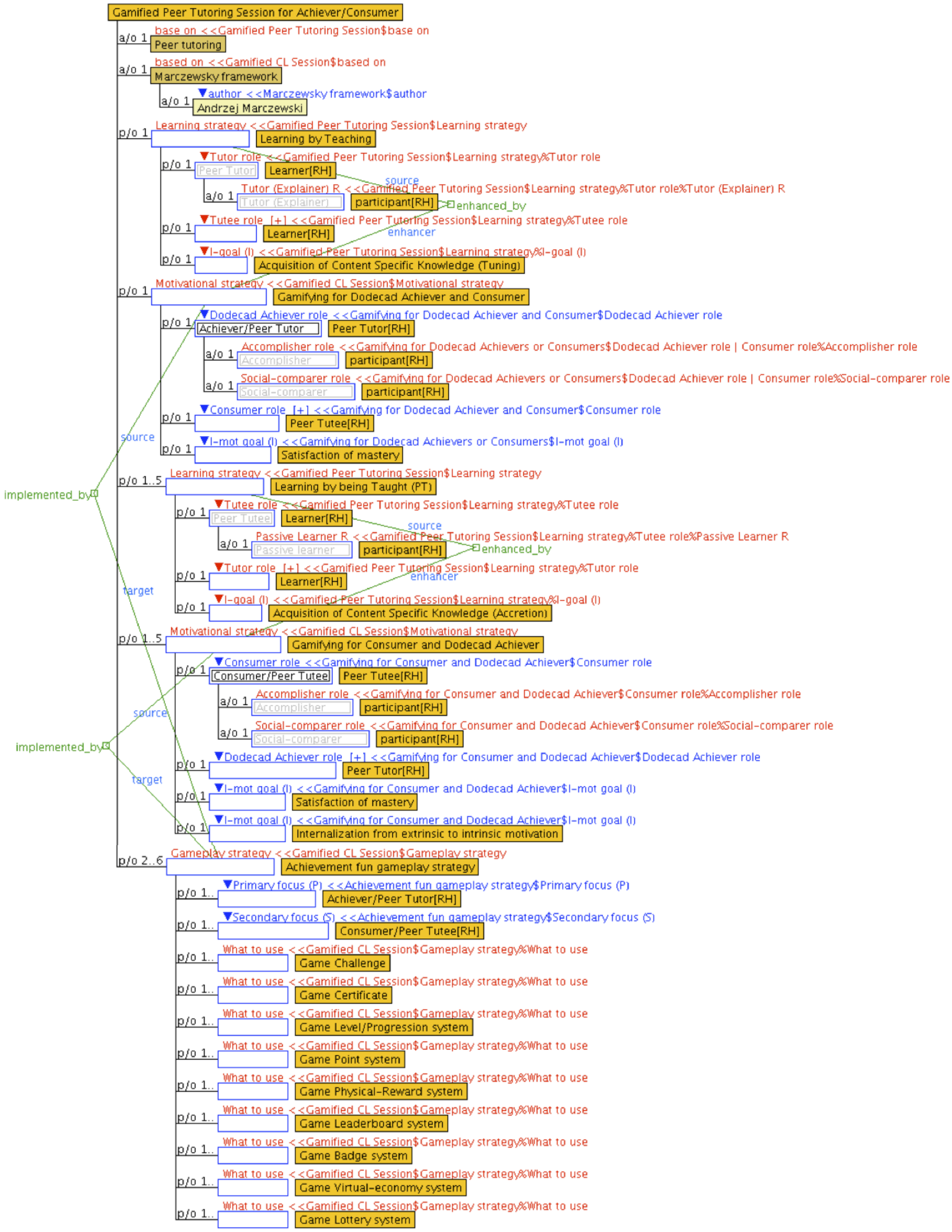
3.4 Concluding Remarks

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/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, 2006), 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 15 – Ontological structure to represent “*Gamified Peer Tutoring Scenario for Achiever/Consumer*”



Source: Elaborated by the author.

CHAPTER

4

ONTOLOGICAL STRUCTURES OF PERSUASIVE GAME DESIGN IN COLLABORATIVE LEARNING SCENARIOS

In the previous chapter, ontological structures have been formalized in the ontology OntoGaCLeS to represent the personalization of gamification in CL scenarios based on player type models. These ontological structures have been proposed to support the definition of player roles and the selection of game elements for each participant in a CL scenario. However, to deal with the motivation problem caused by the scripted collaboration, it is also necessary to provide support for the design of CL gameplay. This design consists into setting up the selected game elements to persuade the participants to follow the interactions defined by a CSCL script. To accomplish this, gamification as Persuasive Game Design (PGD) should be linked to the design of CL process in the modeling of gamified CL scenarios.

This chapter present the ontological structures proposed by the author of this PhD thesis dissertation to represent the connection between PGD and the design of CL process for gamified CL senarios. This connection intends to solve the context-dependency of gamification related to the non-game context and target behaviors being gamified. Thus, the first section (section 4.1) presents a nested-structure proposed to identify things that belong to the gamification world, game world and non-game world. Having this clearly separation, the formalization of PGD as ontological structures is presented in section 4.2. Then, ontological structures to represent the connection of PGD and the design of CL process are presented in the section 4.3 (*Modeling CL Gameplay Based on Persuasive Game Design*). To demonstrate the usefulness of these ontological structures, section 4.4 shows the formalization of an ontological model to apply gamification as persuasive technology in Cognitive Apprenticeship scenarios. Finally, section 4.5 presents the concluding remarks of this chapter.

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

- "*Steps Towards the Gamification of Collaborative Learning Scenarios Supported by Ontologies*" published in the 17th International Conference on Artificial Intelligence in Education, AIED 2015, held in Madrid, Spain (CHALLCO *et al.*, 2015b).
- "*An Ontological Model to Apply Gamification as Persuasive Technology in Collaborative Learning Scenarios*" published in the 26th Brazilian Symposium on Computer in Education, SBIE 2015, held in Maceió, AL, Brazil (CHALLCO *et al.*, 2015).
- "*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).
- "*An Ontology Framework to Apply Gamification in CSCL Scenarios as Persuasive Technology*" published as Volume 24, Issue 2, in the Brazilian Journal of Computers in Education - RBIE, 2016 (CHALLCO; MIZOGUCHI; ISOTANI, 2016).

4.1 Modeling Game and Non-game Worlds

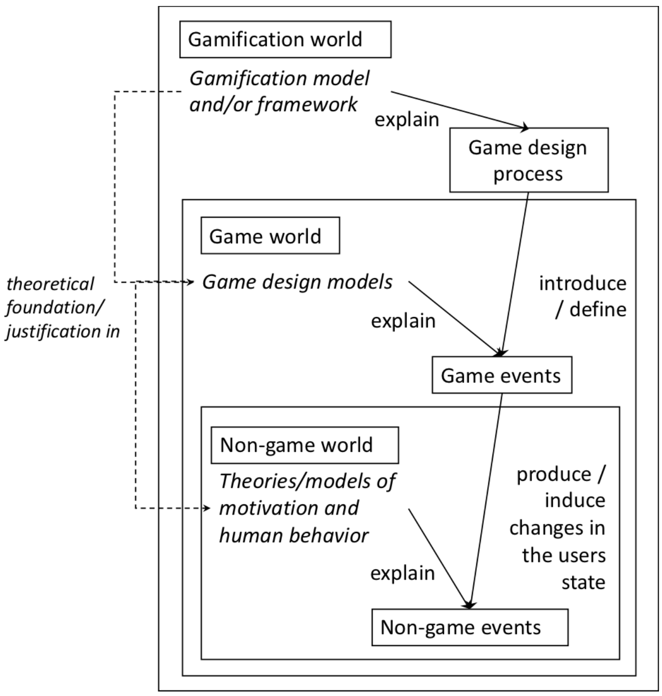
One of the main difficulties to formally represent the gamification in a computer understandable manner is the lack of a clearly separation between game world and non-game world. As was mentioned at the Chapter 2, a game is a problem-solving activity approached with playful attitude (SCHELL, 2008), and a non-game context is being gamified with the intention to make it more game-like (WERBACH, 2014). In this sense, the purpose of gamification is to engender a *gameful attitude*[1] in the students when they are participating in a CL scenario. Hence, to make the interactions defined by a CSCL script more game-liking in a gamified CL scenario, the gamification process consists into add game elements in the environment in which the actions of participants will take place, and to define how these game elements will interact with the participants during the CL process. This gamification process has theoretical foundation in gamification models and/or frameworks to explain a game design process whereby the game elements are introduced and defined in the CL scenarios. The game design model explain how the introduced game elements will interact with the participants to produce and induce changes in the participants' states to approach the CL scenario with a gameful attitude. These changes are theoretically justified through theories/models of motivation and human behavior.

Based on the description of gamification as a process mentioned above, a nested-structure sees adequate to enable a systematic separation of things into gamification world, game world

[1] A gameful attitude is defined here as a playful attitude in which the intrinsic motivation is a necessary condition to achieve this attitude, but the immersion and enjoyment are desirable conditions

and non-game world. Figure 16 shows the nested structure proposed by the author of this PhD thesis dissertation to classify things as being part of the gamification world, game world or non-game world. According to this structure, things belong to the *gamification world* when these things are associated to the *game design process*, things belong to the *game world* when these things are associated to *game events*, and things belong to the *non-game world* when these things are associated to the *non-game events*. The non-game events describe the activities/actions in a process that has the potential to be gamified. The game events describe the activities/action of game elements to make the activities/actions described in the non-game events more game-like. The game design process is a process that describes how to *introduce* and *define* the game events into the system to *produce* and/or *induce changes in the users state* related to the motivation and human behavior. The theoretical justification in this nested-structure for the game design process in the gamification world are given by *gamification models and/or frameworks* that explain the *game design process* used to introduce and to define *game events*; the reasons why these *game events* had been introduced in the non-game situation is explained by *game design models*; and the changes in the users' states produced and/or induced by the game events are explained by *theories/models of motivation and human behavior*.

Figure 16 – Nested structure of non-game world, game world and gamification world



Source: Elaborated by the author.

Employing the nested-structure of non-game world, game world and gamification world (Figure 16), the concepts in the ontology OntoGaCLeS related to the game events and non-game events have been classified in the "*is-a*" hierarchy structure of class shown in Figure 17. This structure categorizes any concept of ontology as a sub-type of classes: *Gamification world*, *Game world*, Non-game world, Common world, and Theory/Model. The classes defined under the categories of common, non-game, game and gamification worlds are concepts for things in their respective worlds, and the concepts formalized as sub-type of *Theory/Model* define the theoretical foundation and justification of gamification and game design.

Gamification world is the class of all things that depend of the gamification world to exist. In this sense, a concept is formalized as sub-type of *Gamification world* whether it represents something that needs of gamification world to be described. For instance, the *Gamification goal/purpose* is a concept formalized as sub-type of Gamification world to describe the goals and/or purposes of a gamification model and/or framework (e.g. *avoiding dropout*, *reducing weariness*). The basic concepts defined as sub-types of *Gamification world* for the gamification of CL scenarios are: *Gamified CL session*, *Motivational strategy* (*Y<=I-mot goal*) by gamification, *Player role*, and *Individual gameplay strategy* (*I-gameplay strategy*).

Game world is the class of all things that depend of the game world to exist. Concepts formalized as sub-types of *Game world* require only elements defined in the games to be described. The basic concept defined as sub-types of *Game world* to gamify CL scenarios is: *Game element*. *Non-game world* is the class of all things that does not need concepts from the *Gamification world* or *Game world* to exist. The non-game world is divided in the sub-types: *Learning world*, *Instructional world*, *World of cognition*, *ID-ISD world*, *CL world*, and *World of motivation and human behavior*. Basic concepts defined as one of these world only need things from its respectively world to exist. Thus, for instance, the concepts formalized as sub-type of *World of motivation and human behavior* represent things that only need elements from motivation and human behavior to exist, so that the basic concepts related to the gamification of CL scenarios formalized as sub-types of *World of motivation and human behavior* are: Individual motivational goal (*I-mot goal*), *Motivation stage*, and *Human need stage*.

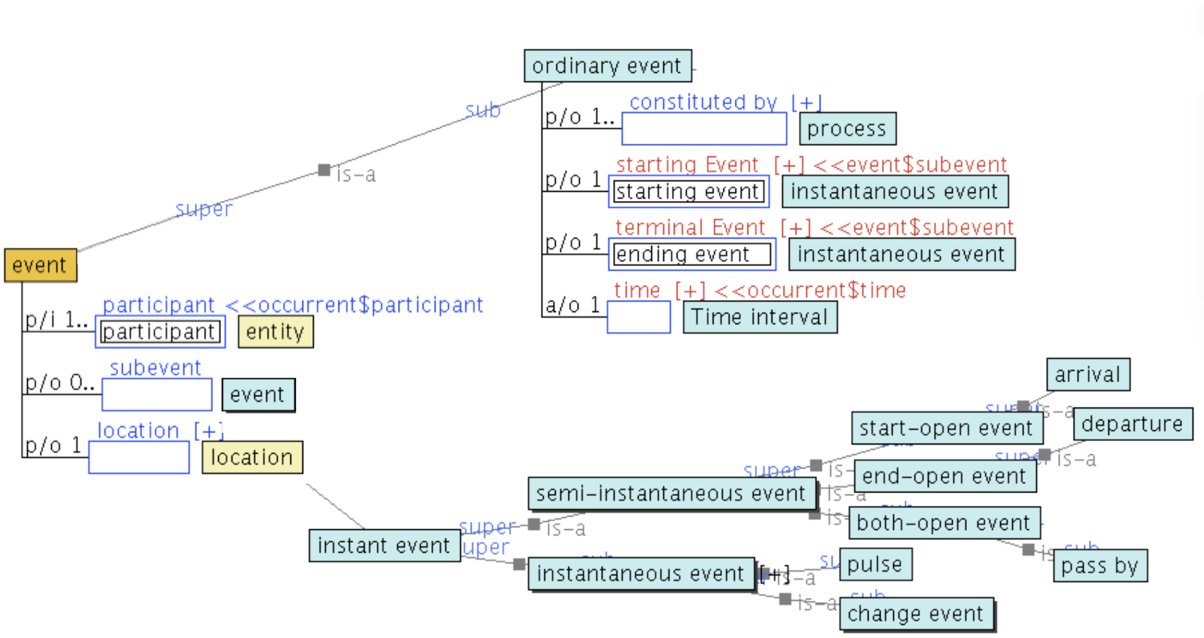
Common world is the class of anything used to represent things that require concepts of other worlds to be formalized. These concepts are common to the other worlds, and they have been taxonomically classified taking as base the classification defined in the upper-level ontology **YAMATO** – ***Y**et **A**nother **M**ore **A**dvanced **T**op-level **O**ntology* (MIZOGUCHI, 2010). The basic concepts in the *Common world* to represent persuasive game design are the concepts of: (i) *action*, (ii) *entity* (e.g. *object*, *agent*), (iii) *state*, and (iv) *event*. These concepts, their sub-types, and their ontological structures have been formalized following the formalization proposed by Galton and Mizoguchi in the article "*The Water Falls but the Waterfall Does Not Fall: New Perspectives on Objects, Processes and Events*" (GALTON; MIZOGUCHI, 2009). According to these definitions, there is a mutual dependency between processes and entities whereby no one process (*action*) can exist without an entity (*agent* or *object*) to enact it, and an entity is what it is as consequence of its processes. Therefore, an entity has properties knows as *states* that change over time when processes are enacted by the object. An *event* is then defined as integration of entities, actions, and states in a particular context to describe a fixed chunk of any process in which the participants of process are the agents and objects.

Figure 17 – “*is-a*” hierarchy structure of classes to represent concepts in the ontology OntoGaCLeS

Source: Elaborated by the author.

Figure 18 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 17). 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 18 – Ontological structures to represent events



Source: Elaborated by the author.

4.2 Modeling Persuasive Game Design

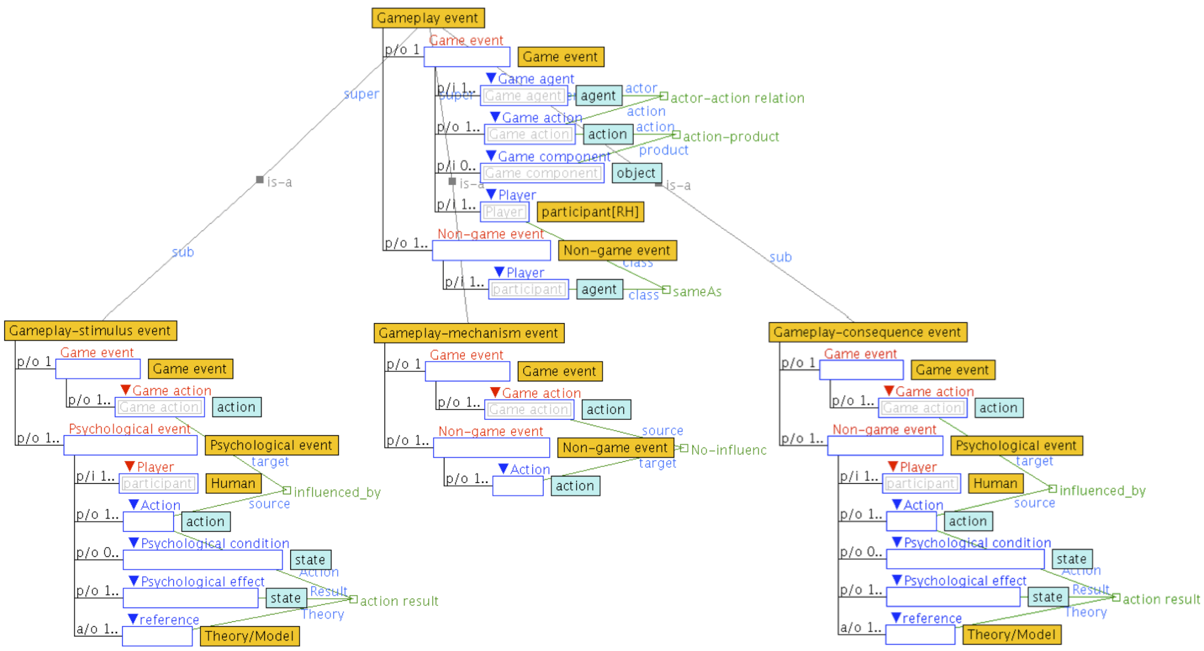
Persuasive Game Design (PGD) is defined as "*the game design for the purpose to change peoples' attitudes, intentions, motivations and/or behaviors through persuasion and social influence without using coercion and/or deception*." In this sense, to represent the PGD as ontological structures, an ontology-based 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 19 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 19 – 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.

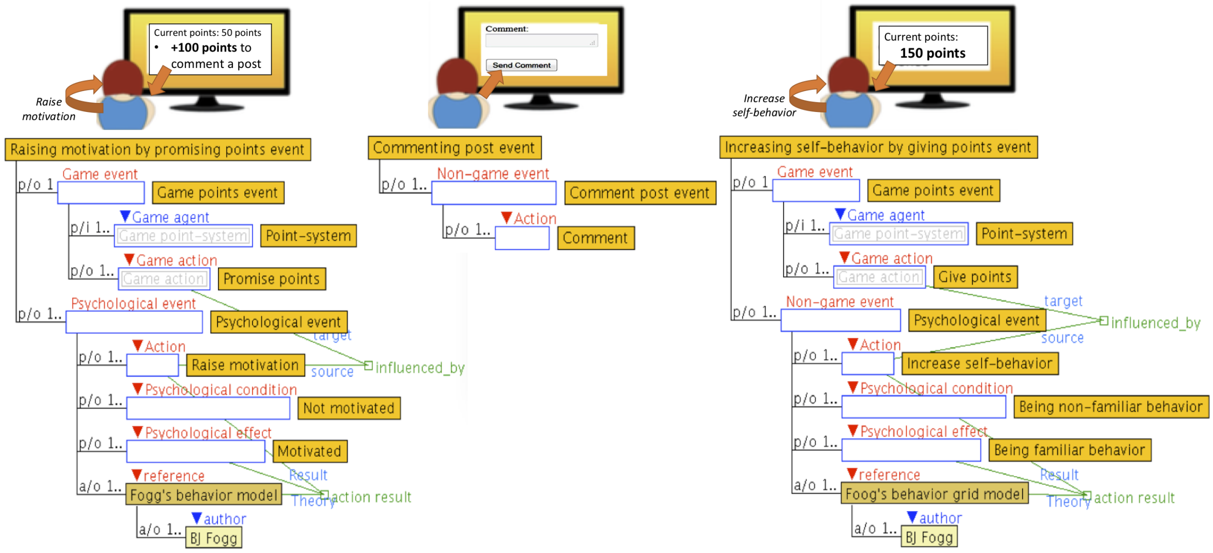


Source: Elaborated by the author.

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 19, 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 19, 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 20. This storyboard as ontological structures is formalized at the bottom of Figure 20, 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 20 – 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.



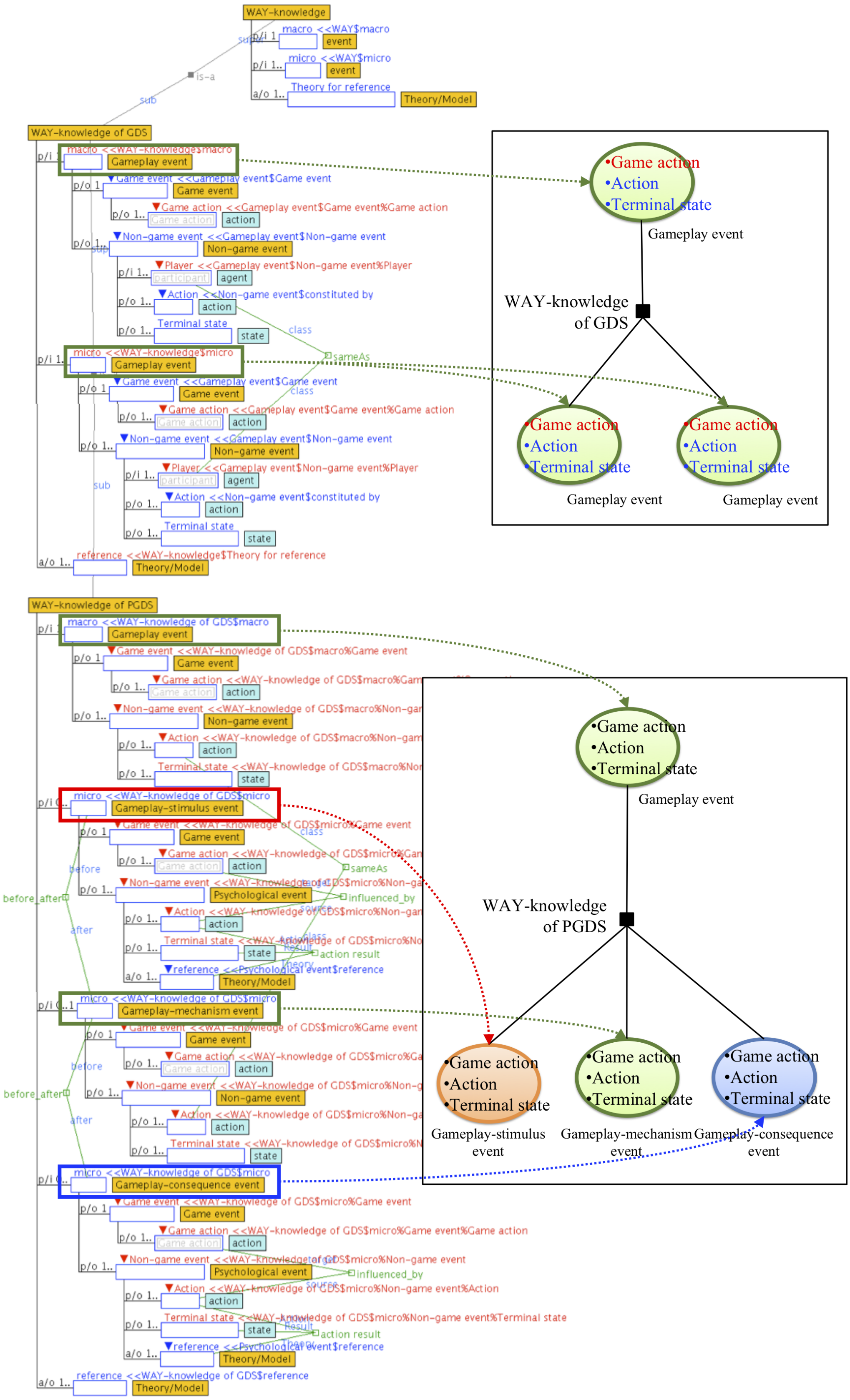
Source: Elaborated by the author.

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 21 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 21 – Ontological structures to represent "*WAY-knowledge of PGDS*."

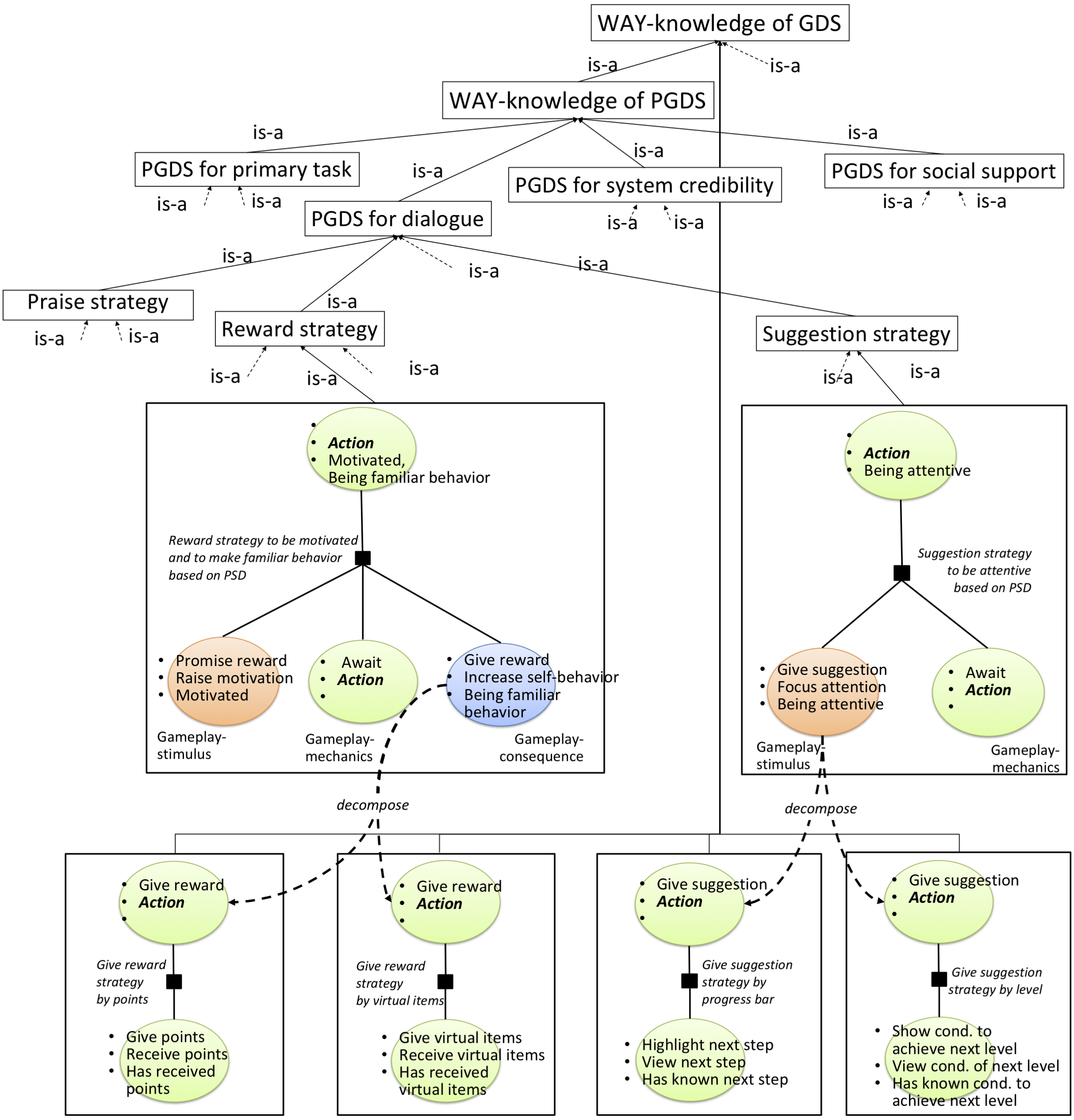


Source: Elaborated by the author.

On the left side of the Figure 21, 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 21), a WAY-knowledge base of GDSs and PGDSs has been defined in the ontology OntoGaCLeS. Part of this base is shown in Figure 22, 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 22 – A portion of the WAY-knowledge base of game design strategies and persuasive game design strategies defined in the ontology OntoGaCLeS



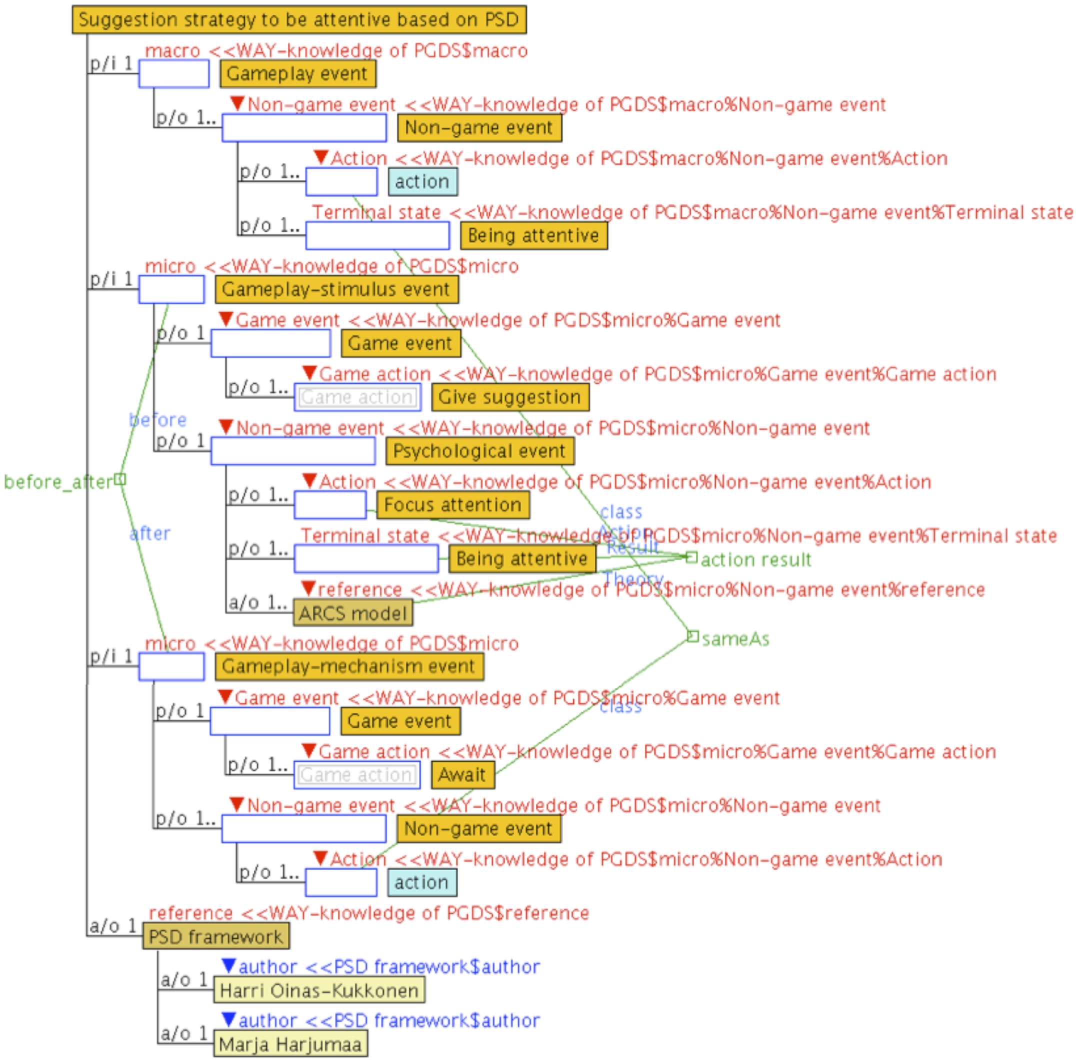
Source: Elaborated by the author.

Figure 22 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 23, 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 23 – Ontological structure to represent the "*Suggestion strategy to be attentive based on PSD*"

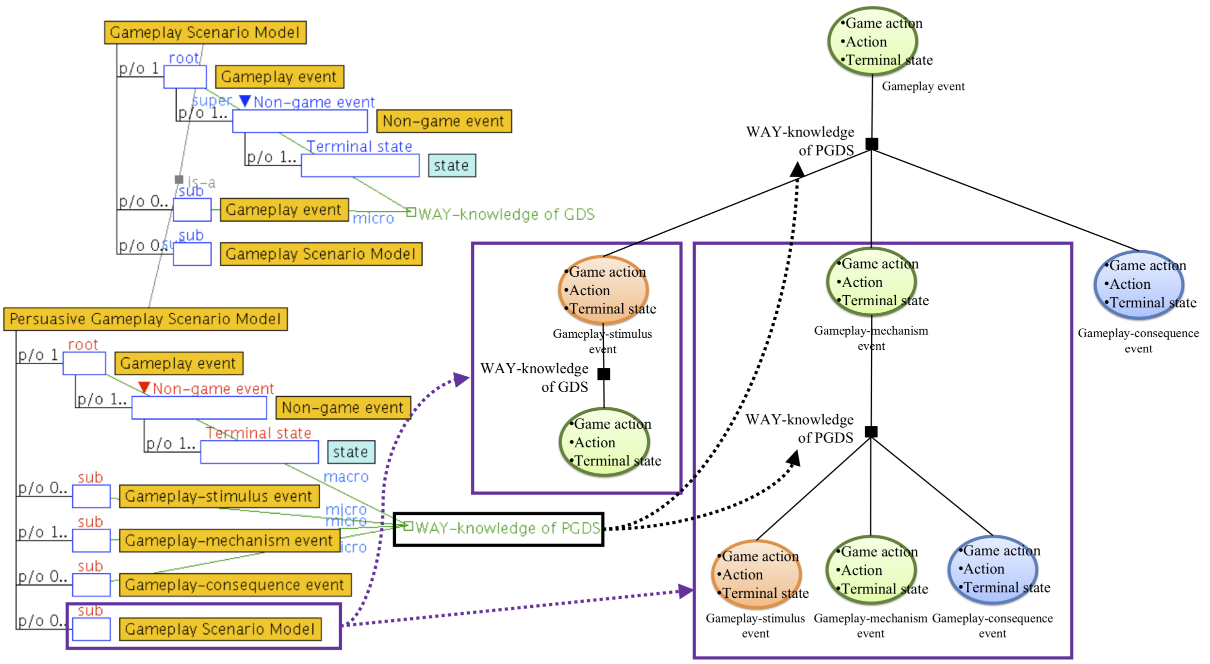


Source: Elaborated by the author.

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 24 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.

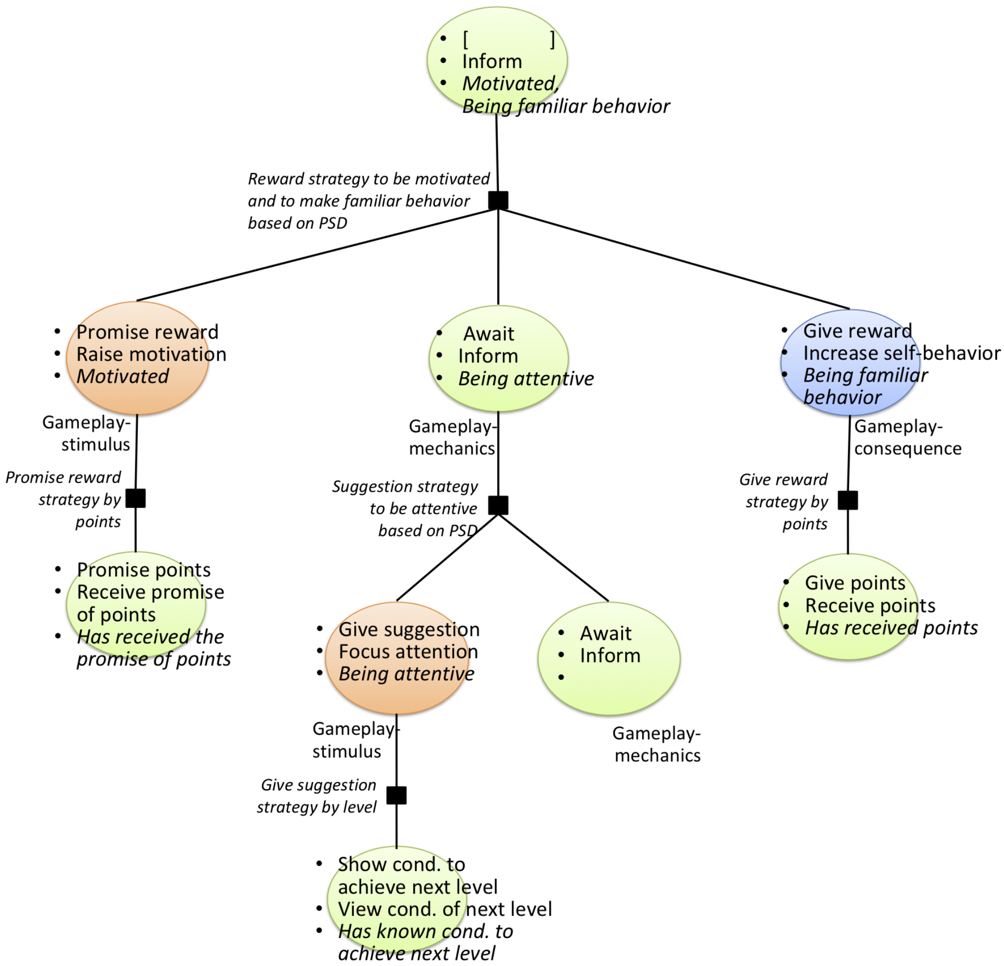
Figure 24 – Ontological structures to represent a "*Persuasive Gameplay Scenario Model*"



Source: Elaborated by the author.

An example of persuasive gameplay scenario model is shown in Figure 25. 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*."

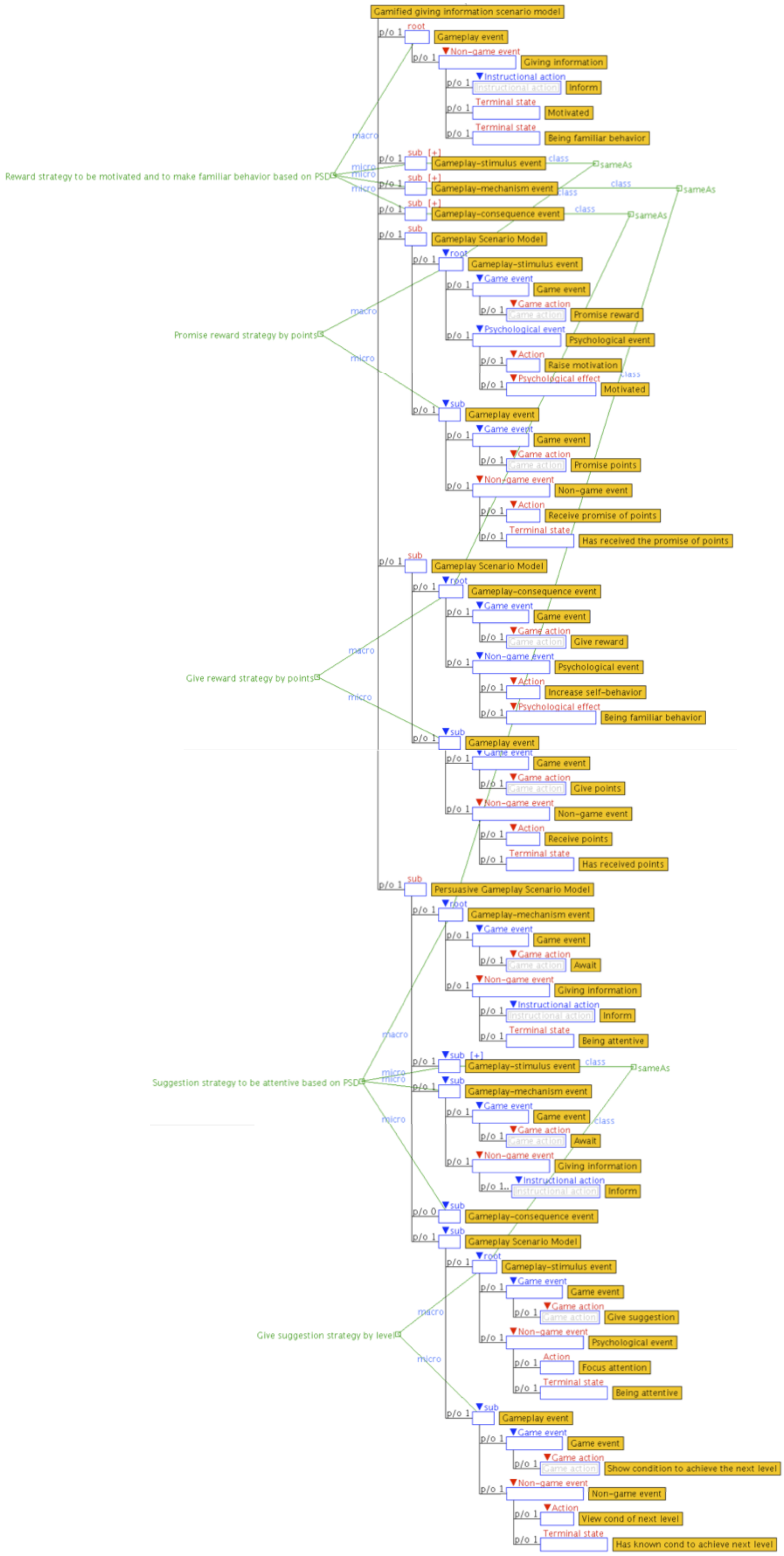
Figure 25 – Example of persuasive gameplay scenario model for the gamification of *Giving information*



Source: Elaborated by the author.

Figure 26 presents the ontological structure formalized to represent the persuasive gameplay scenario model shown in Figure 25. 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 26 – 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

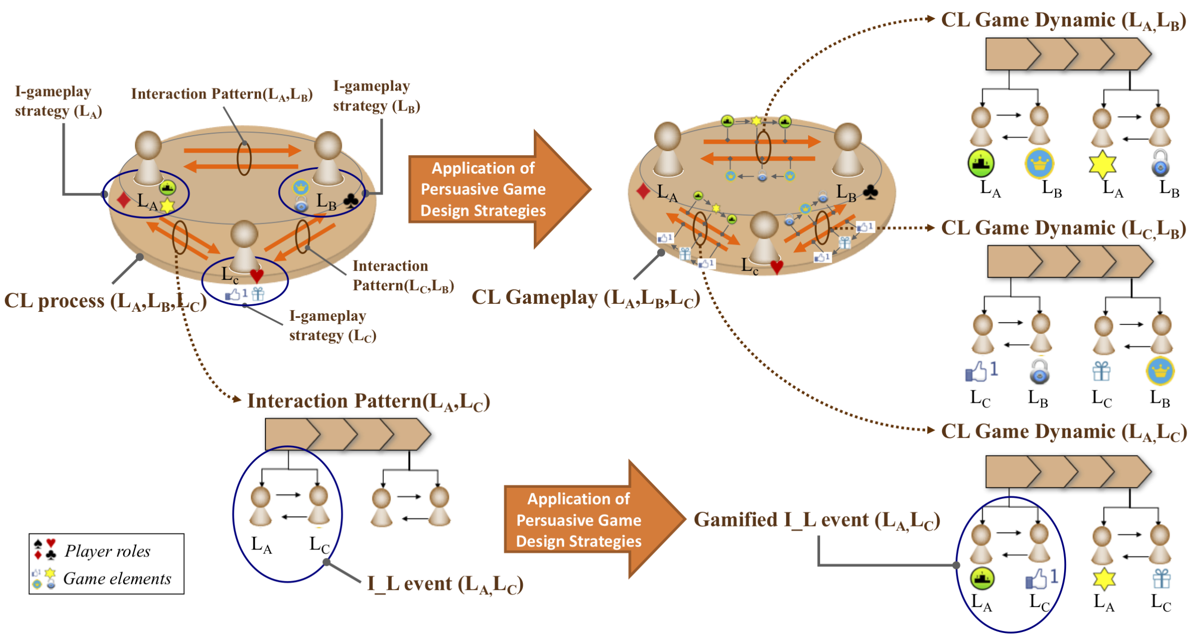
Having the ontological structures to represent Persuasive Game Design Strategies (PGDSs) and the rational design about how to successively apply them, we can procedure to link the design of CL process and the PGD for dealing with the motivation problem caused by the scripted collaboration. This link was established by the modeling of CL gameplay based on PGD. The concepts, terms and relations defined in this modeling are shown in Figure 27, 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 27 – Concepts, terms and relations in the modeling of CL gameplay based on PGD



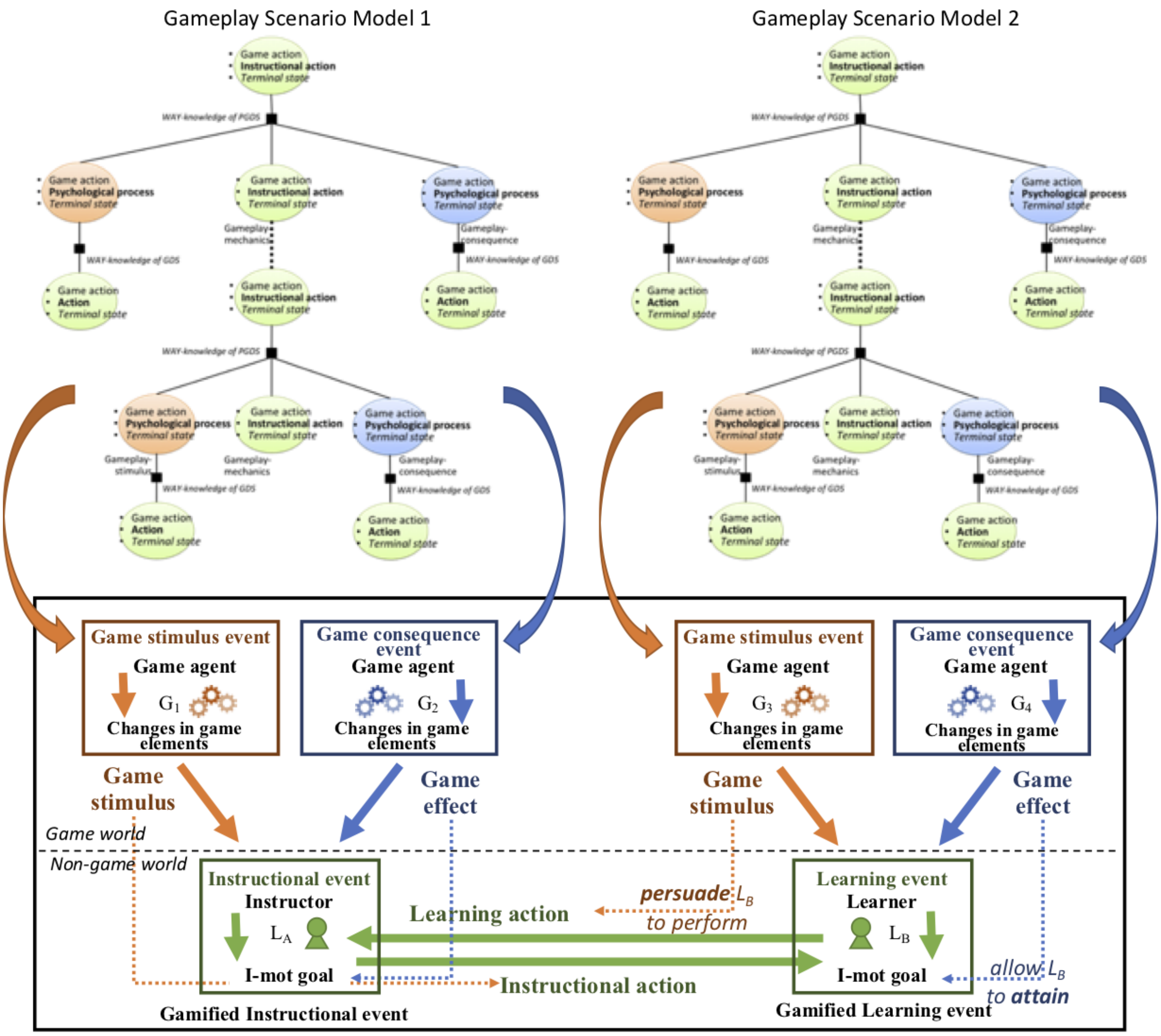
Source: Elaborated by the author.

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 28, 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 28 – Elements in a gamified I_L event

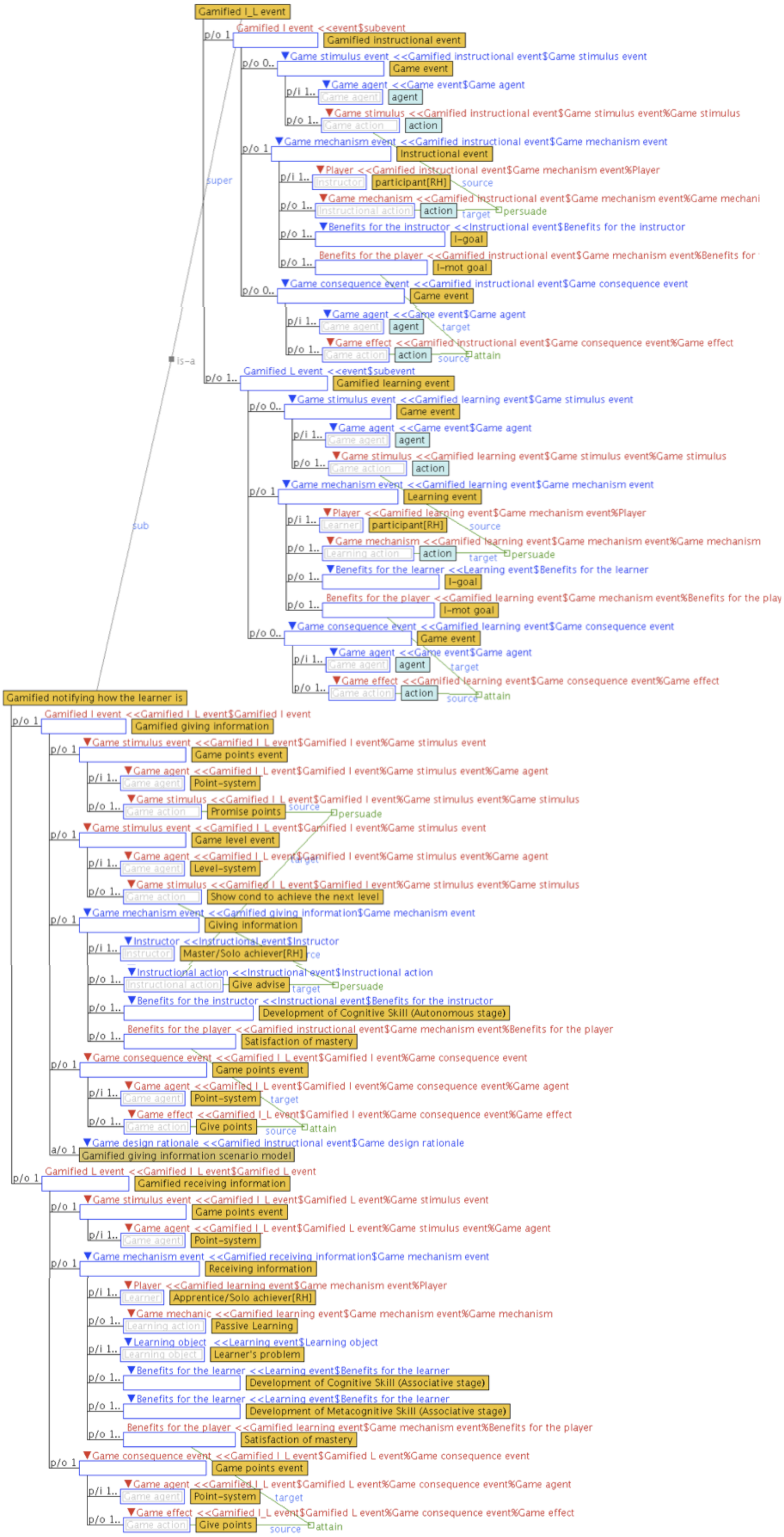


Source: Elaborated by the author.

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 28, 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 29. 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.

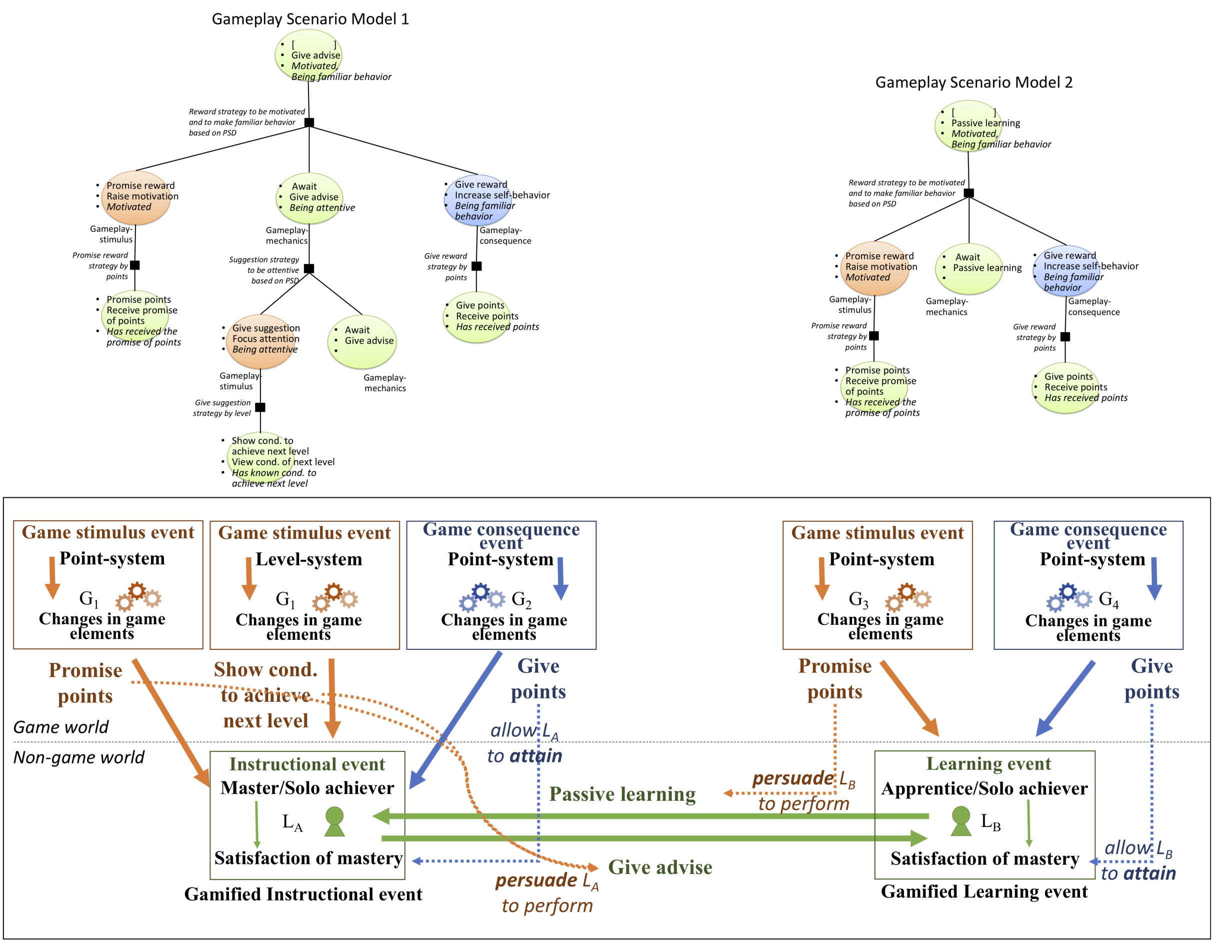
Figure 29 – Ontological structure to represent a “*Gamified I_L event*” (at the top). At the bottom, an example of Gamified I_L event “*Gamified Notify how the learner is*” as ontological structure.



Source: Elaborated by the author.

At the bottom of Figure 29, there is shown the ontological structure to represent a Gamified I_L event "*Gamified Notify how the learner is*" illustrated in Figure 30. 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*.

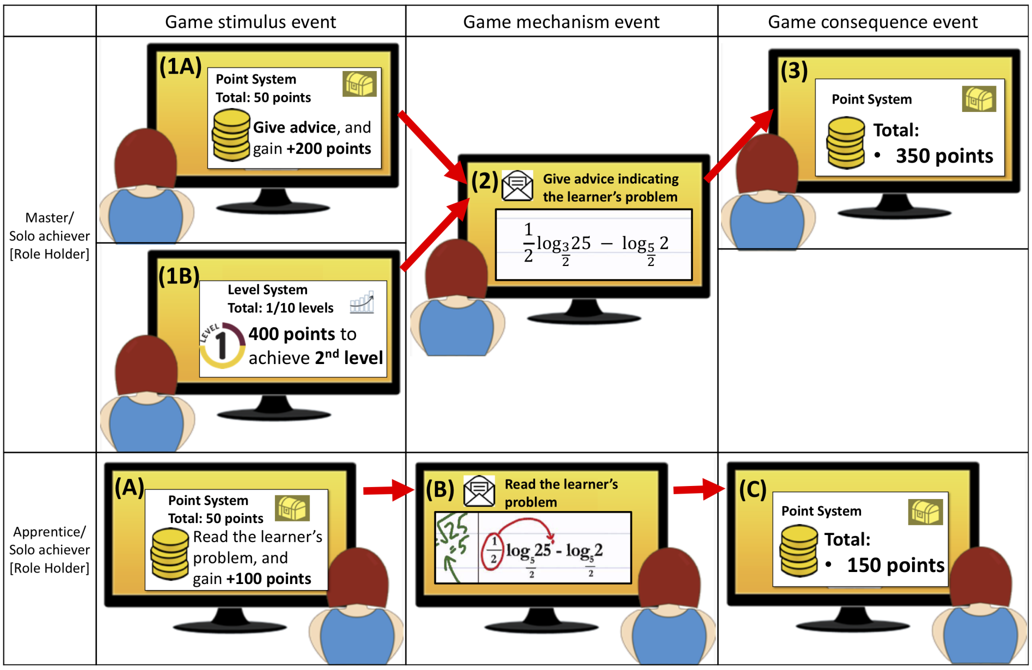
Figure 30 – Elements in an example of gamified I_L event "*Gamified Notify how the learner is*."



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 29 and with the elements illustrated in Figure 30, the interactions between participants and game elements can be established in the CL scenario according to the storyboard shown in Figure 31. 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 31 – 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 31. This configuration is established according to the information provided by the ontological structure shown at the bottom of Figure 29. 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)).

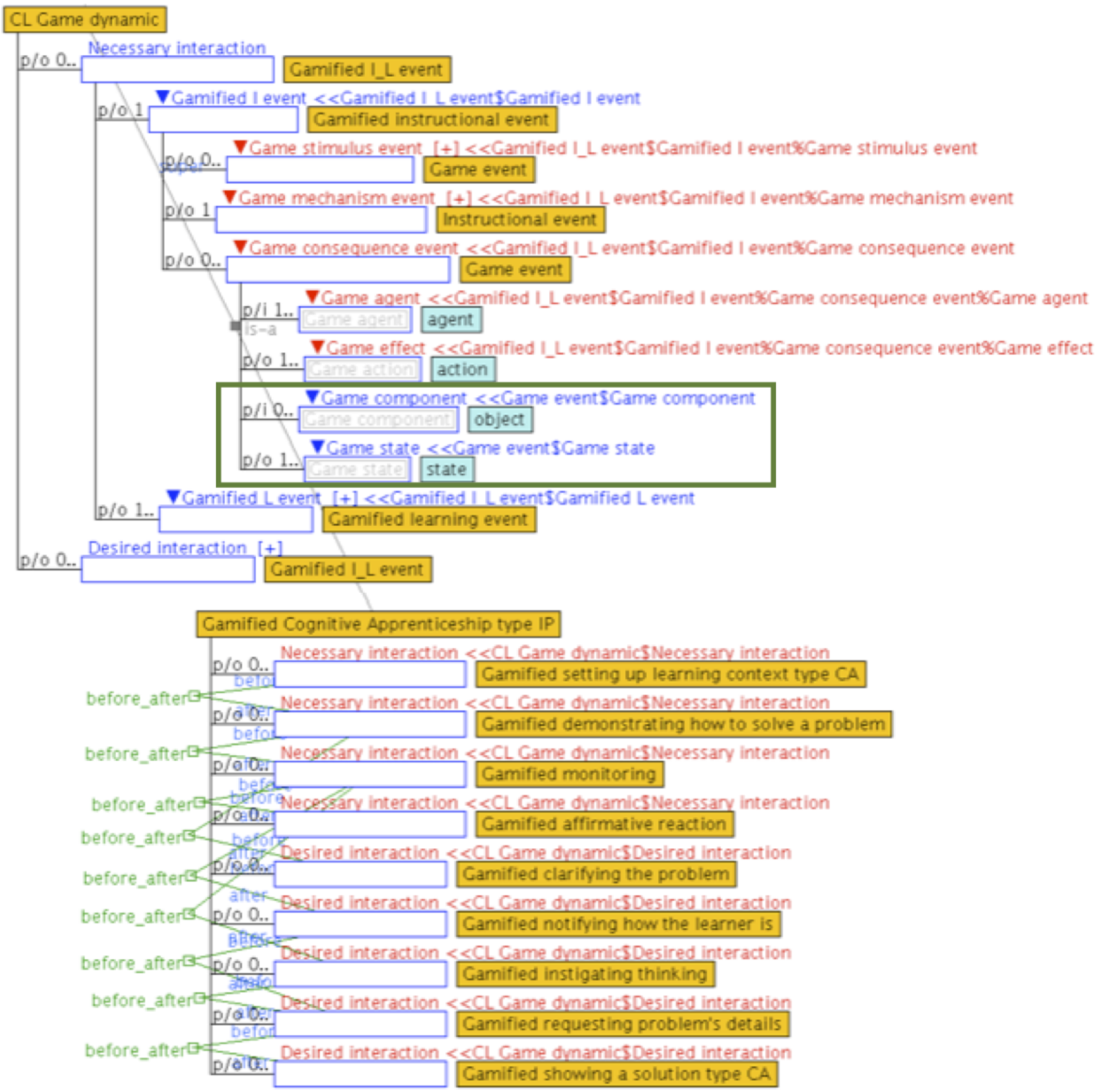
The task of setting up the game actions to be performed by the game agents can be supported by an intelligent system that is able to reason on ontologies. Thus, the designer just needs to have a clear idea of individual motivational goals (*I-mot goal*) to be achieved by the instructor and learner in 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 32 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 32 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 32. 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 32 – 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.



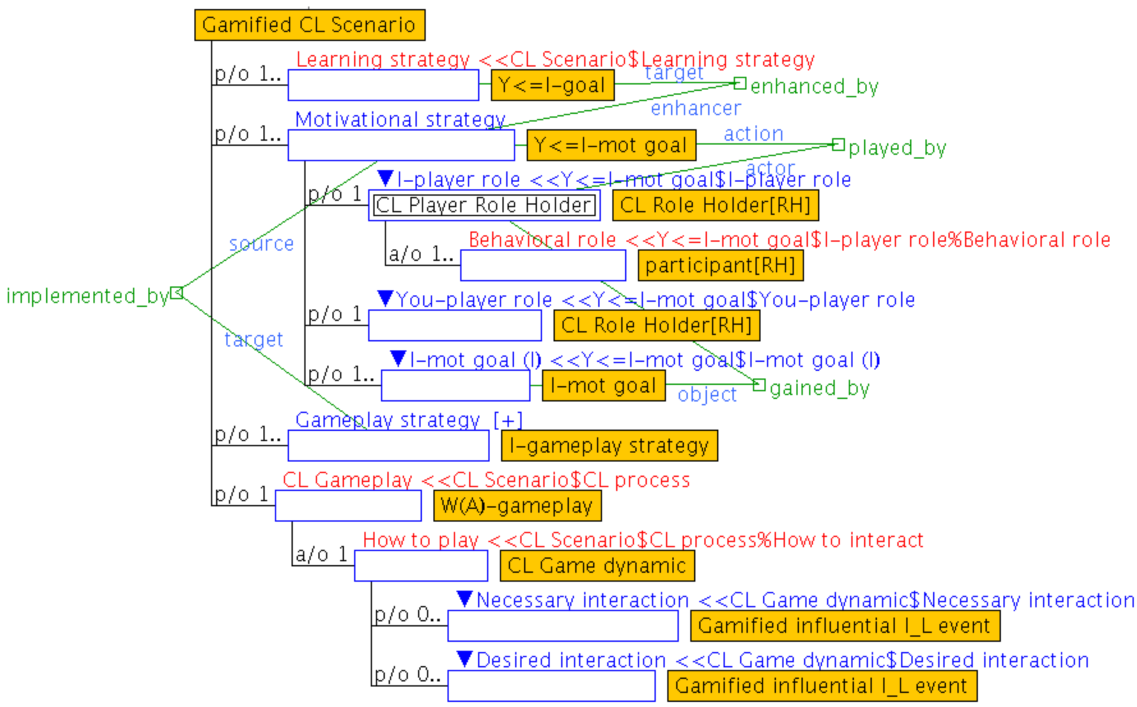
Source: Elaborated by the author.

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 33, 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 33 – Ontological structure to represent a "*Gamified CL Scenario*."



Source: Elaborated by the author.

4.4 Formalizing an Ontological Model to Apply Gamification as Persuasive Technology in CL Scenarios

To demonstrate the applicability of the ontological structures presented in the previous sections, the building of an ontological model to apply gamification as persuasive technology in CL scenarios is detailed in this section. By gamification as persuasive technology, the author of this thesis refers to the use of game design elements to persuade and social influence the participants to change their attitudes, intentions, motivation and/or behaviors. Thus, an ontological model to apply gamification as persuasive technology in CL scenarios has the purpose to provide enough information for setting up the game elements to persuade the participants to follow the interactions defined by a CSCL script. The ontological model detailed here has been proposed to apply gamification as persuasive technology in CL scenarios based on the Cognitive Apprenticeship theory, and the information used to built this model comes from the Yee's model (YEE, 2006) and Model-driven persuasive game proposed by Orji (2014).

The steps for building an ontological model to apply gamification as persuasive in CL scenarios are: (1) to identify the Persuasive Game Design Strategies (PGDSs) for player role holders who are in the *primary focus* (P) and *secondary focus* (S) of individual gameplay strategies (*I-gameplay strategy*); (2) to apply the identified PGDSs in the interaction pattern; and (3) to define the game states and game components in the CL Game Dynamics to provide a gameplay experience according to the individual gameplay strategies.

Step (1): Identifying persuasive game design strategies for player role holders who are in the primary focus and secondary focus of individual gameplay strategies

Several researchers have pointed the necessity to personalize the application of persuasive strategies due to the adverse reactions that can be caused in a person when inappropriate strategies are applied. For instance, a study of Kaptein, Lacroix and Saini (2010) demonstrates that the use of non-tailored persuasive strategies produces negative reactions increasing the adoption of unhealthy behavior. Another example is the study carried out by Orji, Vassileva and Mandryk (2014) in which the effectiveness of PGDSs for player types of BrainHex model was evaluated to identify the best and worst strategies to motivate health behavior change. Thus, to identifying the PGDSs for player role holders who are in the primary focus and secondary focus of individual gameplay strategies, it is necessary to have the list of PGDSs that cause positive and negative impacts in the player roles of ontological model being built.

Table 4 shows the (P)ositive and (N)egative (counterproductive) impacts for the player types of BrainHex model identified in the Model-driven persuasive game proposed by Orji (2014). The PGDSs that cause the most (P)ositive and (N)egative impacts for are indicated with bold texts. The relation of BrainHex player types with the component motivations identified in the Yee's model is indicated in the column "*Yee's Model*," and it has been extracted from the study of

Nacke, Bateman and Mandryk (2014) in which, for instance, the BrainHex's Mastermind player type is related to the Yee's *Mechanics* component motivation because people who are classified in these both player types enjoys to devise strategies for solving puzzles and problem, because they obtain pleasure when they make good decisions. The column "*Player role*" indicates the relation between the PGDSs and the player roles based on the Yee's model.

Table 4 – Persuasive game design strategies for player types of BrainHex and Yee's model

BrainHex	**CMPT/ CMPR**	**COOP**	**CUST**	**PERS**	**PRAS**	**SEMT/ SUGG**	**SIML**	**REWD**	**Yee's Model**	**Player Role**
Achiever		**(P)**				(P)		(P)	*Advancement*	
Mastermind	(P)		(P)	(P)		**(P)**	(P)		*Mechanics*	Yee Achiever
Conqueror	**(P)**			(P)		(P)	(P)		*Competition*	
Socializer	(P)	**(P)**	(N)		(N)	**(N)**			*Social*	Yee Socializer
Seeker	(P)		**(P)**	(P)	(P)				*Immersion*	
Survivor	(P)	**(N)**	(N)			**(P)**		(N)	*Escapism*	Dreamer
Daredevil	(N)					**(N)**	**(P)**		*Escapism*	
Achiever		**(P)**				(P)		(P)	*Advancement*	
Mastermind	(P)		(P)	(P)		**(P)**	(P)		*Mechanics*	Social Achiever
Conqueror	**(P)**			(P)		(P)	(P)		*Competition*	
Socializer	(P)	**(P)**	(N)		(N)	**(N)**			*Social*	
Achiever		**(P)**				(P)		(P)	*Advancement*	
Mastermind	(P)		(P)	(P)		**(P)**	(P)		*Mechanics*	
Conqueror	**(P)**			(P)		(P)	(P)		*Competition*	Achiever Dreamer
Seeker	(P)		**(P)**	(P)	(P)				*Immersion*	
Survivor	(P)	**(N)**	(N)			**(P)**		(N)	*Escapism*	
Daredevil	(N)					**(N)**	**(P)**		*Escapism*	
Socializer	(P)	**(P)**	(N)		(N)	**(N)**			*Social*	
Seeker	(P)		**(P)**	(P)	(P)				*Immersion*	Social Dreamer
Survivor	(P)	**(N)**	(N)			**(P)**		(N)	*Escapism*	
Daredevil	(N)					**(N)**	**(P)**		*Escapism*	
Achiever		**(P)**				(P)		(P)	*Advancement*	
Mastermind	(P)		(P)	(P)		**(P)**	(P)		*Mechanics*	
Conqueror	**(P)**			(P)		(P)	(P)		*Competition*	
Socializer	(P)	**(P)**	(N)		(N)	**(N)**			*Social*	Full Gamer
Seeker	(P)		**(P)**	(P)	(P)				*Immersion*	
Survivor	(P)	**(N)**	(N)			**(P)**		(N)	*Escapism*	
Daredevil	(N)					**(N)**	**(P)**		*Escapism*	

CMPT/CMPR: competition & comparison, COOP: cooperation, CUST: customization, PERS: personalization, PRAS: praise, SEMT/SUGG: self-monitoring & suggestion, SIML: simulation, REWD: reward

With the list of PGDSs that can be applied in the player roles, a combination of PGDSs is carried out for the player role holders who are in the primary focus and secondary focus of the individual gameplay strategies. During this combination, the PGDSs that cause negative impacts are avoided. Thus, for example, for the player role holders: "*Yee Achiever*" as primary focus (P), and "*Socializer*" as secondary focus (S); the combination of PGDSs consists in the strategies of *CMPT/CMPR*, *COOP*, *PERS*, *SIML*, and *REWD* in which the counterproductive PGDSs avoided for this combination were *CUST*, and *SEMT/SUGG* because these PGDSs have negative influence for the Yee Socializer player role. Table 5 shows the combination of PGDSs for the player role holders based on the Yee's model. Strikethrough text in this table indicates a counterproductive PGDS.

Table 5 – Persuasive game design strategies for player role holders who are in the primary focus and secondary focus of individual gameplay strategies based on Yee's model

Primary focus (P) x **S-Player**	**Yee Socializer**	**Yee Achiever**	**Dreamer**	**Social Achiever**	**Achiever Dreamer**	**Social Dreamer**	**Full Gamer**
Yee Socializer	COOP, CMPT/CMPR	COOP, CMPT/CMPR x ~~SEMT/SUGG~~, CMPT/CMPR, COOP, PERS, SIML, REWD, ~~CUST~~	~~COOP~~, ~~CMPT/CMPR~~ x SIML, PRAS, PERS	COOP, CMPT/CMPR x CMPT/CMPR, COOP, PERS, SIML, REWD	~~COOP~~, ~~CMPT/CMPR~~ x SIML, PERS, ~~PRAS~~	~~COOP~~, ~~CMPT/CMPR~~ x SIML, PERS	~~COOP~~, ~~CMPT/CMPR~~ x SIML, PERS
Yee Achiever	~~SEMT/SUGG~~, CMPT/CMPR, COOP, PERS, SIML, REWD, ~~CUST~~ x COOP, CMPT/CMPR	SEMT/SUGG, CMPT/CMPR, COOP, PERS, SIML, REWD, CUST	~~SEMT/SUGG~~, ~~CMPT/CMPR~~, ~~COOP~~, PERS, SIML, ~~REWD~~, ~~CUST~~ x SIML, PRAS, PERS	~~SEMT/SUGG~~, CMPT/CMPR, COOP, PERS, SIML, REWD, ~~CUST~~ x CMPT/CMPR, COOP, PERS, SIML, REWD	~~SEMT/SUGG~~, ~~CMPT/CMPR~~, ~~COOP~~, PERS, SIML, ~~REWD~~, ~~CUST~~ x SIML, PERS, PRAS	SEMT/SUGG, CMPT/CMPR, COOP, PERS, SIML, REWD, CUST x SIML, PERS	SEMT/SUGG, CMPT/CMPR, COOP, PERS, SIML, REWD, CUST x SIML, PERS
Dreamer	SIML, PRAS, PERS x ~~COOP~~, ~~CMPT/CMPR~~	SIML, PRAS, PERS x ~~SEMT/SUGG~~, ~~CMPT/CMPR~~, ~~COOP~~, PERS, SIML, ~~REWD~~, ~~CUST~~	SIML, PRAS, PERS	SIML, PRAS, PERS x CMPT/CMPR, COOP, PERS, SIML, REWD	SIML, PRAS, PERS x SIML, PERS, PRAS	SIML, PRAS, PERS x SIML, PERS	SIML, PRAS, PERS x SIML, PERS
Social Achiever	CMPT/CMPR, COOP, PERS, SIML, REWD x COOP, CMPT/CMPR	CMPT/CMPR, COOP, PERS, SIML, REWD x ~~SEMT/SUGG~~, CMPT/CMPR, COOP, PERS, SIML, REWD, ~~CUST~~	CMPT/CMPR, COOP, PERS, SIML, REWD x SIML, PRAS, PERS	CMPT/CMPR, COOP, PERS, SIML, REWD	CMPT/CMPR, COOP, PERS, SIML, REWD x SIML, PERS, PRAS	CMPT/CMPR, COOP, PERS, SIML, REWD x SIML, PERS	CMPT/CMPR, COOP, PERS, SIML, REWD x SIML, PERS

CMPT/CMPR: competition & comparison, COOP: cooperation, CUST: customization, PERS: personalization, PRAS: praise, SEMT/SUGG: self-monitoring & suggestion, SIML: simulation, REWD: reward

Table 5 – *(continued)*

Secondary focus (S) **S-Player**	**Yee Socializer**	**Yee Achiever**	**Dreamer**	**Social Achiever**	**Achiever Dreamer**	**Social Dreamer**	**Full Gamer**
Achiever Dreamer	SIML, PRAS, ~~PERS~~ x ~~COOP~~, ~~CMPT/CMPR~~	SIML, PRAS, PERS x ~~SEMT/SUGG~~, ~~CMPT/CMPR~~, ~~COOP~~, PERS, SIML, ~~REWD~~, ~~CUST~~	SIML, PRAS, PERS x SIML, PRAS, PERS	SIML, PRAS, PERS x CMPT/CMPR, COOP, PERS, SIML, REWD	SIML, PRAS, PERS	SIML, PRAS, PERS x SIML, PERS	SIML, PRAS, PERS x SIML, PERS
Social Dreamer	SIML, PERS x ~~COOP~~, ~~CMPT/CMPR~~	SIML, PERS x SEMT/SUGG, CMPT/CMPR, COOP, PERS, SIML, REWD, CUST	SIML, PERS x SIML, PRAS, PERS	SIML, PERS x CMPT/CMPR, COOP, PERS, SIML, REWD	SIML, PERS x SIML, PRAS, PERS	SIML, PERS	SIML, PERS x SIML, PERS
Full Gamer	SIML, PERS x ~~COOP~~, ~~CMPT/CMPR~~	SIML, PERS x SEMT/SUGG, CMPT/CMPR, COOP, PERS, SIML, REWD, CUST	SIML, PERS x SIML, PRAS, PERS	SIML, PERS x CMPT/CMPR, COOP, PERS, SIML, REWD	SIML, PERS x SIML, PRAS, PERS	SIML, PERS x SIML, PERS	SIML, PERS

CMPT/CMPR: competition & comparison, COOP: cooperation, CUST: customization, PERS: personalization, PRAS: praise, SEMT/SUGG: self-monitoring & suggestion, SIML: simulation, REWD: reward

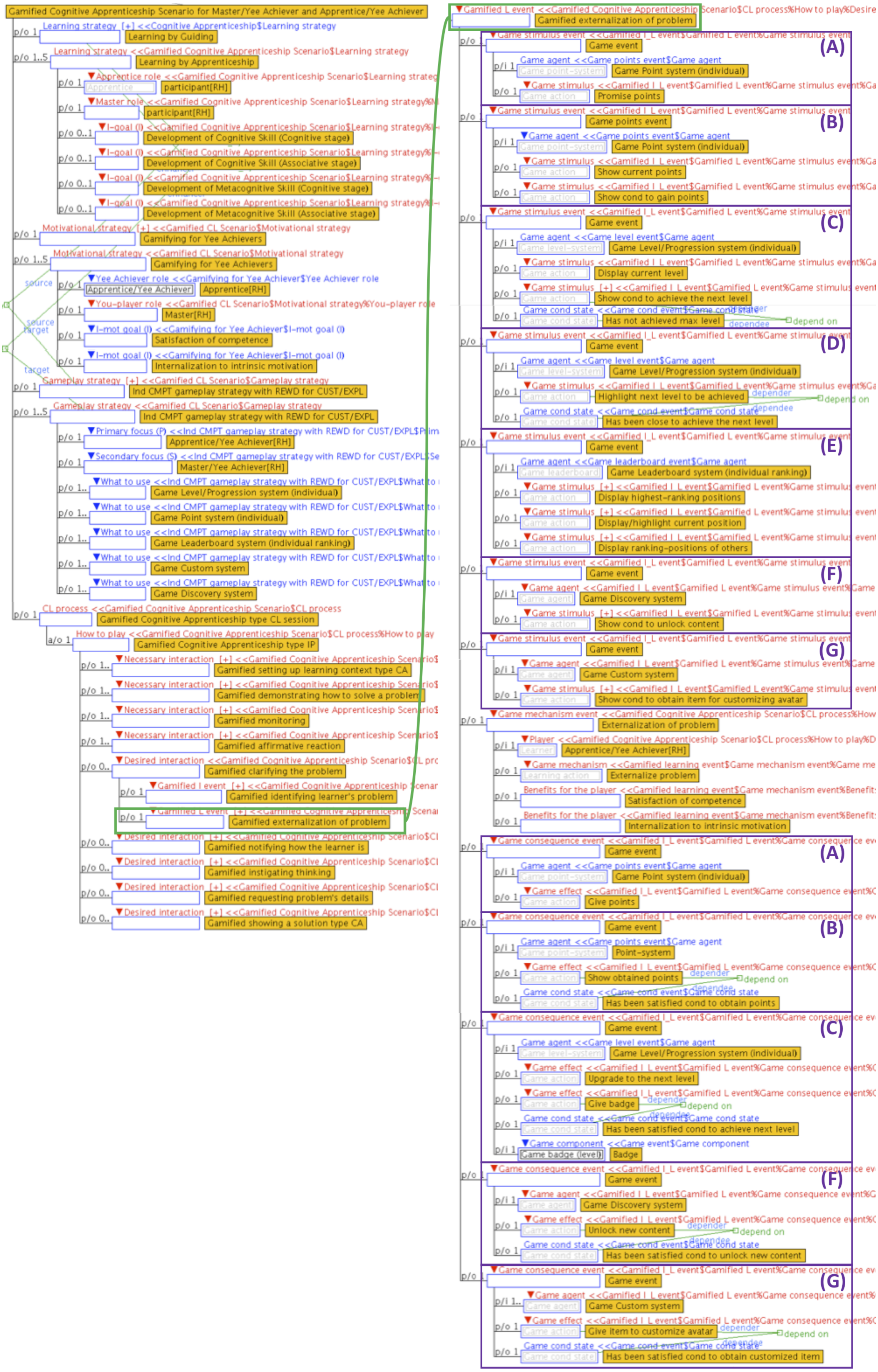
Step (2): Applying persuasive game design strategies in the interaction pattern

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 Table 5, 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 34 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 34 – Ontological structure to represent a "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever.*"



Source: Elaborated by the author.

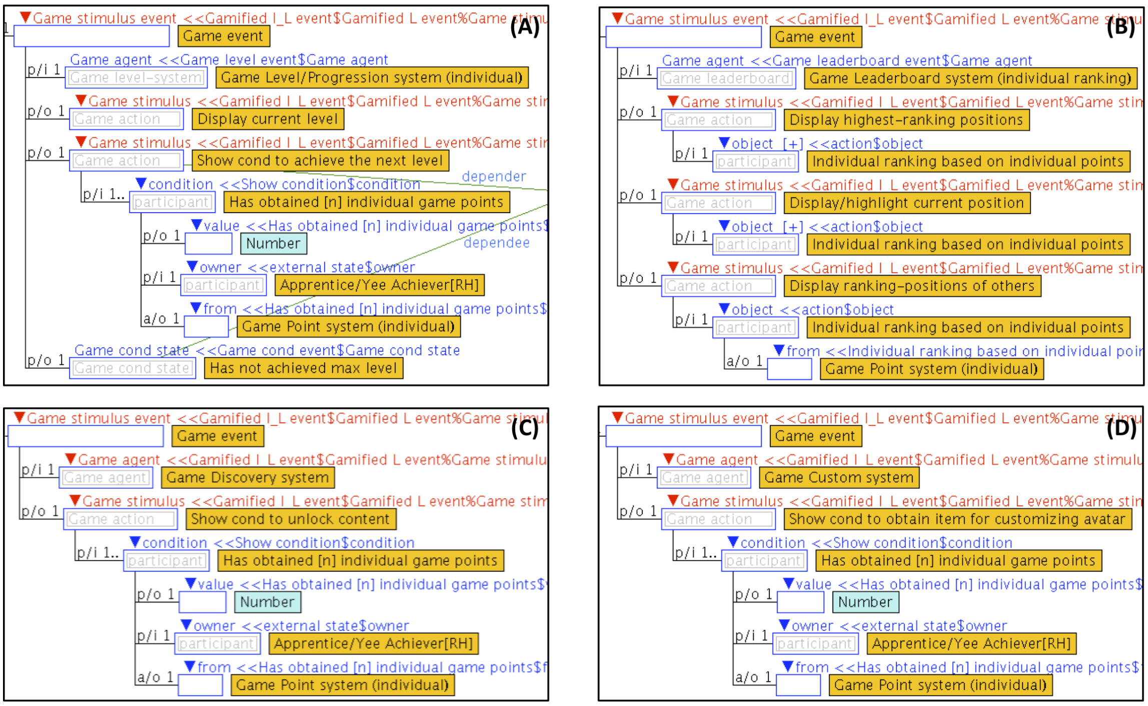
On the right side of Figure 34 is detailed the gamified learning event "*Gamified externalization of problem*" that is result of applying the combination of PGDSs "*SEMT/SUGG, CMPT/CMPR, COOP, PERS, SIM, REWD, CUST*" to gamify the learning event "*Externalization of problem*." The application of the 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 35 (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 35 (B).

Figure 35 – 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 35 (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 35 (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]*."

4.5 Concluding Remarks

Gamification as persuasive technology has been formalized in this chapter as the application of Persuasive Game Design Strategies (PGDSs) in non-game events to gamify them. Thus, to represent the knowledge involved in this process as ontological structures, the author of this thesis has proposed a nested structure of non-game world, game world and gamification world to identify, classify and differentiate the elements related to non-game events and game events. With this classification, the link between the Persuasive Game Design (PGD) and the design of CL process is represented in explicitly form by *gameplay events*. The prescriptive representation of the link between PGD and the design of CL process has been formalized by means of *WAY-knowledge of PGDS*. This formalization is accomplished through the representation of "*What*" and "*How*" to achieve expected changes in person's attitudes, intentions, motivations and/or behaviors to persuade him/her to perform the actions specified in the non-game events. The design rationale in the application of PGDs to gamify a non-game event has been formalized as the concept of "*Gameplay Scenario Model*," and it is used to gamify instructional and learning events defined in interactions patterns based on the sequencing mechanism of a CSCL script. Thus, the pairs of gamified instructional and learning events has been formalized as ontological structures under the concept of *Gamified I_L event* to represent an interaction in the CL process. As result of the application of PGDSs in the interaction pattern, a *CL Game dynamic* is obtained to establish a *CL Gameplay* in a gamified CL scenario.

The usefulness of the ontological structures proposed here has been demonstrated by the formalization of an ontological model to apply gamification as persuasive technology in gamified CL scenarios based on the Cognitive Apprenticeship theory and with the player roles based on the Yee's model. The application of PGDSs to apply gamification as persuasive technology has the purpose to engender gameplay experiences of individual and cooperative competition based on the information extracted from the Model-driven persuasive game proposed by Orji (2014).

To solve the context-dependency of gamification in CL scenarios to persuade the participants to follow the interactions defined by the sequencing mechanism of a CSCL script, computer-based mechanisms can be built to help the design of CL gameplay in gamified CL scenarios. This support is given by information extracted from ontological models to apply gamification as persuasive technology in which the ontological structures to represent gamified I_L events are used to establish the interactions between participants and game elements in the environment to run the gamified CL scenarios. Employing the formalization of WAY-knowledge of PGDS, computer-based mechanisms that support the building of a WAY-knowledge base of PGDSs can be built and computer-based mechanism that support the building of ontological models to apply gamification as persuasive technology in gamified CL scenarios. These computer based mechanism will be presented in Chapter 6.

CHAPTER

5

A UNIFY MODELING OF LEARNER'S GROWTH PROCESS AND FLOW THEORY

In the learning process, the affective state of students plays an essential role that influences several mechanisms of rational thinking and learning (D'MELLO, 2012; PICARD, 2000; REIS *et al.*, 2015). Students with negative affective states (e.g. boredom) during the learning process are, in general, significantly more likely to obtain inadequate learning outcomes, because they often are not motivated and are not engaged in the learning process (CRAIG *et al.*, 2004; SHERNOFF *et al.*, 2014). In this sense, to motivate a student so that he/she participates in a learning scenario with complete immersion, it is necessary that his/her affective state provide an optimal experience. This affective state is denominated flow, and it is a mental state of operation characterized by a feeling of energized focus, full involvement, and success in the task being performed (CSIKSZENTMIHALYI, 2008).

To define a gamified CL scenario with game elements that favor and maintain the participants in the flow state during the CL process, it is necessary to have understanding about the influence of these game elements in the affective state of participants. One condition for attaining and maintaining the flow state is the good balance between the perceived challenges of the tasks that will be carried out, and the participant's own perceived abilities to accomplish these tasks. A task that is perceived too challenging or one that is not challenging enough may lead to anxiety or boredom, and when a person perceives that he/she does not have enough ability or he/she has too ability to carry out the task, he/she would be anxious or bored. Thus, a model known as GMIF model: "*Learner's **G**rowth **M**odel **I**mproved by **F**low Theory*" to integrate the learner's growth process and the third condition of good balance between the perceived challenges and ability is presented in this chapter.

This chapter is organized as follows: The first section provides details about the Learner's Growth Model (LGM model) and the three-channel flow model (section 5.1). Then, the GMIF model is presented in section 5.2. To demonstrate the usefulness of the GMIF model, section 5.3

illustrates how this model can be used to establish the game rewards that will be given to the participants in a gamified CL scenario to maintain them in the flow state. Finally, section 5.4 presents the concluding remarks.

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

- "*Toward A Unified Modeling of Learner's Growth Process and Flow Theory*" published in the International Journal of Educational Technology & Society, Vol. 19, No. 2, April 2016 (CHALLCO *et al.*, 2016).

5.1 Learner's Growth Model and Three-channel Flow Model

5.1.1 Learner's Growth Model

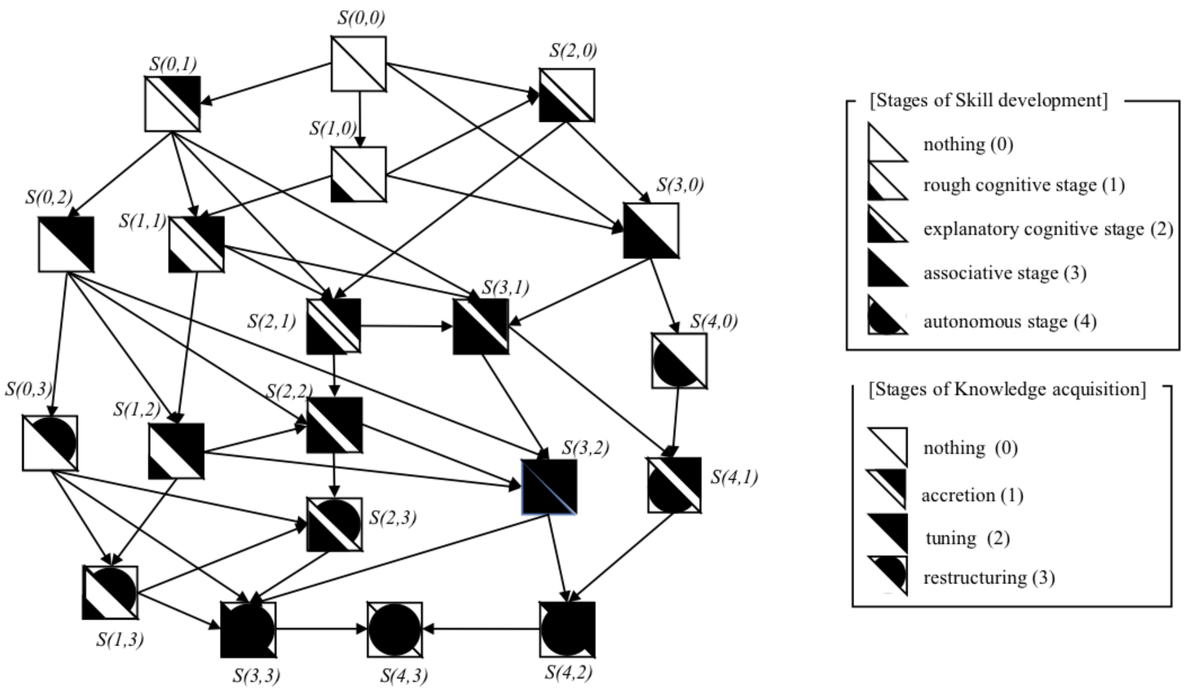
Based on learning theories, the "***L**earners **G**rowth **M**odel*" (LGM model) is a graph that represents the learning process of a student as stages of skill development and knowledge acquisition as a directed graph (INABA; IKEDA; MIZOGUCHI, 2003; ISOTANI; MIZOGUCHI, 2006). The learner's growth process is represented as paths on the graph that allow for the representation of the relationships between learning strategies and their educational benefits.

As shown in Figure 36, the LGM model has twenty states that are the result of the number of stages related to skill development multiplied by the number of stages related to knowledge acquisition. In the graph, the stages of skill development (nothing, rough cognitive, explanatory cognitive, associative, and autonomous) are represented in the lower-left triangle, while the stages of knowledge acquisition (nothing, accretion, tuning, and restructuring) are represented in the upper-right triangle. In skill development, the cognitive stage (rough, and explanatory) involves an initial encoding of a target skill that allows the learner to present the desired behavior or, at least, some rough approximation thereof; the associative stage is the improvement of the desired skill through practice; and the autonomous stage involves gradual continued improvement in the performance of the skill (ANDERSON, 1982). During knowledge acquisition, the accretion stage incorporates the addition and interpretation of new information in terms of pre-existent knowledge; the tuning stage involves coming to understand the knowledge through its application in a specific situation; and the restructuring stage comprises a process in which the relationship of the acquired knowledge is considered and the existent knowledge structure is rebuilt (RUMELHART; NORMAN, 1976).

The arrows in the LGM model shown in Figure 36 represent possible transitions between stages, and the form $s(x,y)$ on the top of each vertex is the simplified form of representing a stage, where the symbol "x" represents the current stage of skill development, and the symbol "y" represents the current stage of knowledge acquisition. For instance, the transition $s(0,0) \rightarrow s(2,0)$

means the possible transition from the stage $s(0,0)$ where a learner does not have any knowledge or skills to the associative stage $s(2,0)$ of skill development.

Figure 36 – Learner's Growth Model (LGM model)



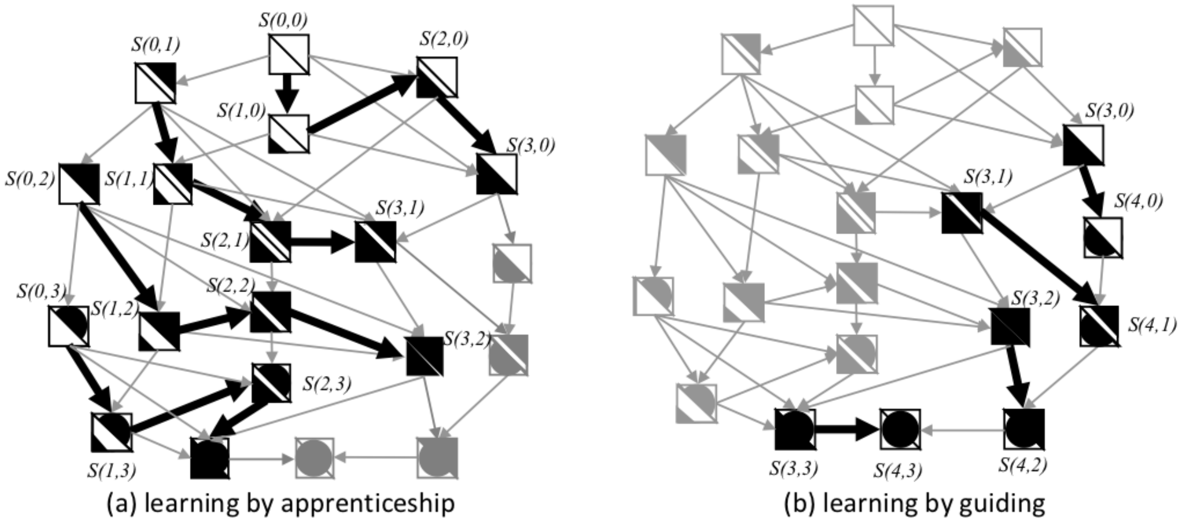
Source: Adapted from Inaba, Ikeda and Mizoguchi (2003).

One of the most interesting uses of this model is the representation of transitions in the skill development and knowledge acquisition stages of participants in CL scenarios based on the learning strategies employed by them and the benefits that different learning theories offer. Figure 37 shows the representation for the transition of stages in the development of skill and acquisition of knowledge involved in a CL scenario based on the cognitive apprentice theory in which the black arrows imply the application of the learning strategies that facilitates the learner's growth process.

On the left side of Figure 37 is shown the transition of stages for the apprenticeship learning strategy, where the transition of stages in the LGM model represent the growing in cognitive skills from $s(0,y)$:*nothing* into the $s(3,y)$:*associative stage* through the $s(1,y)$:*rough-cognitive stage* and the $s(2,y)$:*explanatory-cognitive stage*. These transitions in the skill development are transitions carried out by participants who play the apprentice role. On the right side of Figure 37 is shown the transitions of stages described by the learning strategy "*learning by guiding*" in the LGM model. According to this learning strategy, the participant who plays the master role grows in his/her cognitive skill from the $s(3,y)$:*associative stage* into the $s(4,y)$:*autonomous stage*.

With the use of the LGM model, any learning strategy or educational best practice can be explicitly described as a path on the graph, facilitating the understanding, visualization and utilization of the model (ISOTANI *et al.*, 2010).

Figure 37 – Transitions in the LGM model for cognitive apprenticeship scenarios. On the left side, stages in the learning by apprentice strategy for participants who play the apprentice role. On the right side, stages in the learning by guiding strategy for participants who play the master role



Source: Adapted from Isotani *et al.* (2010).

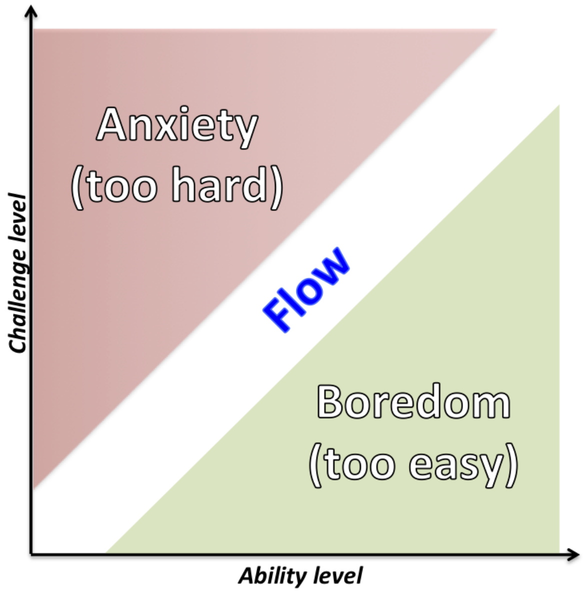
5.1.2 Three-channel Flow Model

Csikszentmihalyi's flow theory constitutes an important theory regarding to affective states of people during activities that require active work, such as discussions, exercises, and group activities (CSIKSZENTMIHALYI, 2014; SNYDER; LOPEZ; PEDROTTI, 2010). This theory has been applied in several fields, including game design, commerce, and education. The key concept of this theory is the "*The Zone Flow*" as a situation in which a person is so engaged and focused on a particular task that he/she is completely immersed in it. According to the flow theory, to achieve the flow state, the following conditions must be satisfied:

- Clear goals in which the expectations and rules are clearly discernable
- Direct and immediate feedback in which the successes and failures of the tasks are apparent, so that behavior can be adjusted as needed
- Good balance between the perceived ability and challenge

One of the conditions given above is that the flow state only occurs if there is a good balance between the perceived challenges of the task at hand and the learner's own perceived ability to solve it. This means that the definition of an appropriate challenge (i.e. level of difficulty) is fundamental to design situations that promotes a flow state (LINEHAN *et al.*, 2014). Thus, Csikszentmihalyi proposes the three-channel flow model (CSIKSZENTMIHALYI, 2008) shown in Figure 38, in which both anxiety and boredom drive persons to frustration. When a task is too difficult to be solved, it causes anxiety because it is perceived as too challenging or 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 38 – 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.

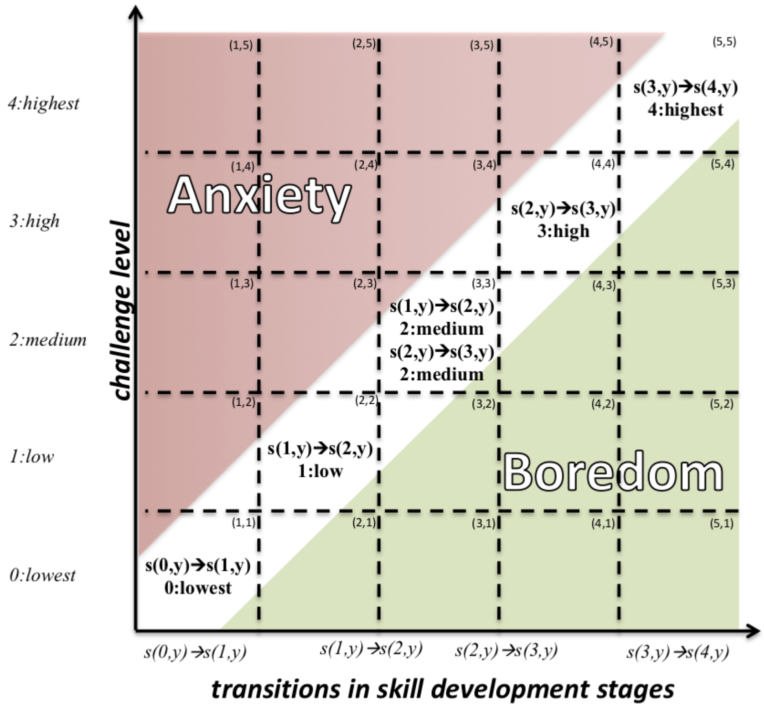
Before to present the algorithm proposed to create a GMIF model with a n-scale of challenge level (*n-scale GMIF model*), a five-scale GMIF model is presented to introduce and detail the elements involved in the building of a GMIF model. After that, the algorithm to create a n-scale GIMF model is presented, 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 39 – Five-scale three-channel flow model of skill development

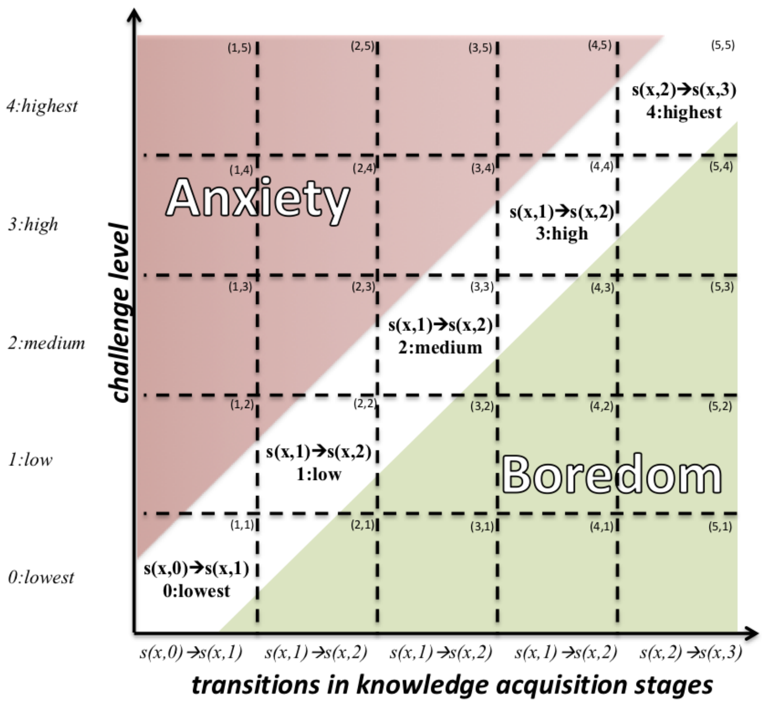


Source: Elaborated by the author.

Figure 39 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 ($s(x,0) \rightarrow s(x,1)$: from *nothing* to *accretion stage*; $s(x,1) \rightarrow s(x,2)$: from the *accretion stage* to *tuning stage*; $s(x,2) \rightarrow s(x,3)$: from the *tuning stage* to *restructuring stage*), the five-scale three-channel flow model shown in Figure 40 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 $s(x,0) \rightarrow s(x,1)$, 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 $s(x,1) \rightarrow s(x,2)$, 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 $s(x,2) \rightarrow s(x,3)$ is 4:*highest*.

Figure 40 – Five-scale three-channel flow model of knowledge acquisition



Source: Elaborated by the author.

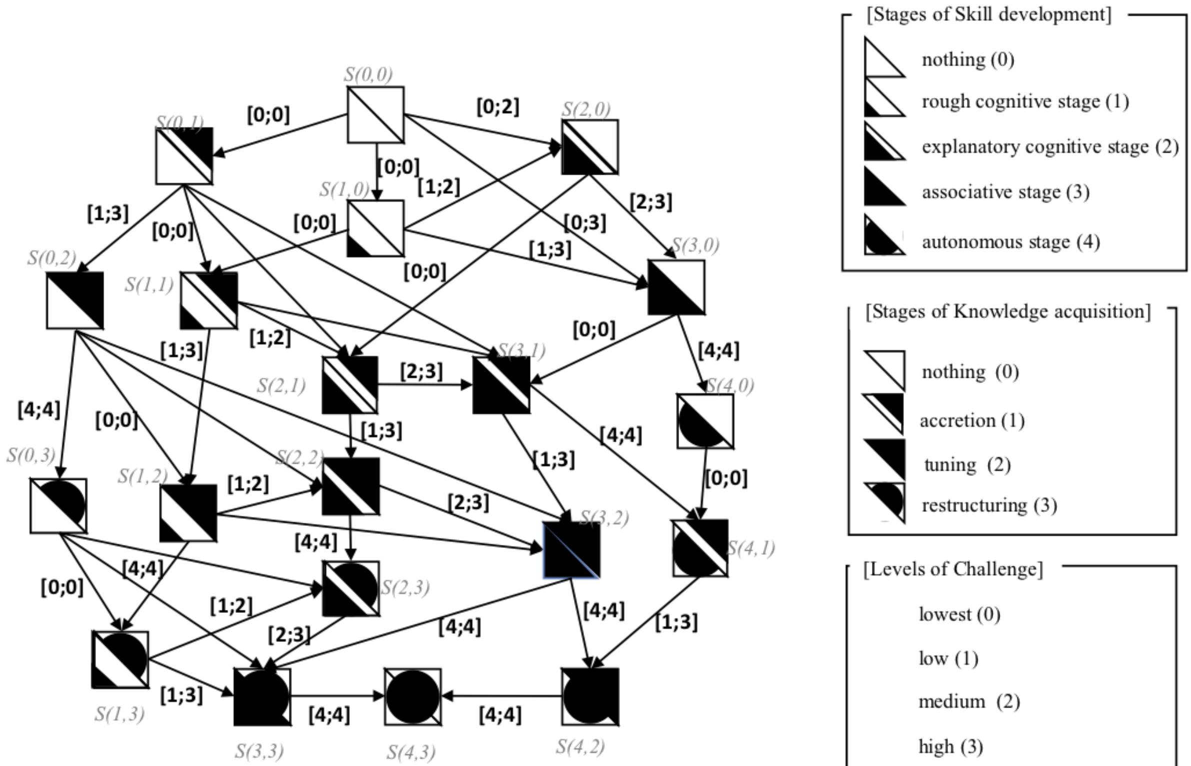
To obtain the five-scale GMIF model, the relationship between the transitions of stages in the skill development and knowledge acquisition and the challenge levels should be clearly understood from the two five-scale three-channel flow models shown in Figure 39 and Figure 40. With this knowledge, it 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 39 and Figure 40, 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.

$s(x,y) \to s(x',y')$) between states in the LGM with a tuple "$[z_{min}; z_{max}]$," where z_{min} refers to the minimum challenge level necessary of to be considered interesting and not too easy, and z_{max} refers to the maximum challenge level possible to be considered challenging but not too difficult.

To define the values of z_{min} and z_{max} in the labels "$[z_{min}; z_{max}]$" of a transition $s(x,y) \to s(x',y')$, the sequences s_1 and s_2 are used to define the proper levels of challenge for the transitions related to skill development and knowledge acquisition, respectively. Thus, when a transition $s(x,y) \to s(x',y)$ is related to the skill development, the sequence s_1 extracted from the model shown in Figure 39 is used to label this transition. For example, to develop skill from the *explanatory-cognitive stage* to the *associate stage*, the transition $s(2,y) \to s(3,y)$ is labeled in the LGM graph as $[2;3]$ by looking at where this transition is located in the flow area of Figure 39. In this particular situation, the label $[2;3]$ means that, to maintain the learner's flow, the level of challenge for an element in the learning scenario should be selected in the range of 2:*medium* to 3:*high*. Following the same procedure, the transitions related to knowledge acquisition are used to label the transitions $s(x,y) \to s(x,y')$ defined by the sequence s_2.

Figure 41 shows the five-scale GMIF model that results from labeling the LGM with a scale of five levels of challenge.

Figure 41 – Five-scale learner's growth model improved by the flow theory



Source: Elaborated by the author.

5.2.2 Algorithm for Building a n-scale GMIF Model

Algorithm 1 shows the algorithm proposed to build a GMIF model with a n-scale of challenge levels (*n-scale GMIF model*), where the expected difference for the levels of challenge in the flow area is passed as the param "*delta*" (as a second argument that has the default value zero). In the algorithm, the variable GMIF contains the labels for the transitions $t = s(x,y) \rightarrow s(x',y')$ of the LGM model, and each label is represented as the form $[z_{min}; z_{max}]$, which indicates the minimum z_{min} and maximum z_{max} levels of challenge that is necessary to maintain a participant is the flow state.

In the algorithm, the flow regions for the "*transitions in skill development stages* vs *challenge level*" and the "*transitions in knowledge development stages* vs *challenge level*" are obtained by the function "*get_flow_region*" (lines 2-3), where the first parameter is the number of transitions for skill development or knowledge acquisition, and the second parameter is the n-scale of space for the challenge level, and the third parameter is the expected difference for levels of challenge.

Algorithm 1 – Algorithm to build a *n*-scale GMIF model

1: **procedure** BUILD_GIMF(n_scale = 5, delta = 0)
2: skill_flow $\leftarrow$ get_flow_region(4, n_scale, delta)
3: knowledge_flow $\leftarrow$ get_flow_region(3, n_scale, delta)
4: **for all** $t = (x,y) \rightarrow (x',y)$ in LGM model **do**
5: GIMF[t] $\leftarrow \cup_{i=x}^{x'-1}$skill_flow[i]
6: **end for**
7: **for all** $t = (x,y) \rightarrow (x,y')$ in LGM model **do**
8: GIMF[t] $\leftarrow$ knowledge_flow[y]
9: **end for**
10: **end procedure**

Because the transition in the skill development stages includes flexibility that allows to increase the skill stage without following all the transitions between stages, transitions $s(x,y) \rightarrow s(x',y)$ are labeled in all levels of challenge that are defined in intermediate transitions as shown in the lines (4-6) of Algorithm 1. For example, it is possible to go from 0:*nothing* to 3:*associative stage* without moving through the intermediate stages 1:*rough-cognitive stage* and 2:*explanatory-cognitive stage*; thus, the transition $s(0,y) \rightarrow s(3,y)$ is labeled with the union of challenge levels defined in the transitions $s(0,y) \rightarrow s(1,y)$, $s(1,y) \rightarrow s(2,y)$ and $s(2,y) \rightarrow s(3,y)$. In the case of transitions related to the knowledge acquisition, the transition of stages is completed step-by-step without skipping any of the stages; thus, the transition $s(x,y) \rightarrow s(x,y')$ is labeled by setting the corresponding levels of challenge for the transitions of knowledge acquisition at shown in lines (7-9) of Algorithm 1.

Algorithm 2 details the algorithm for the function "*get_flow_region*." This function calculates the flow region in the n-scale three-channel flow models, where the flow region is represented as an array of size *m* (number of transitions for skill development or for knowledge acquisition) in which each i-th element contains the levels of challenge for the transition from the i-th stage to the next stage ($i+1$ stage). For an instance of five levels of challenge and three transitions of knowledge acquisition (shown in Figure 40), the flow region as a result of the algorithm is a sequence $s = \{[0;0],[1;3],[4;4]\}$, where the first element "[0;0]" indicates the level of challenge as 0:*lowest* for the transition $s(x,0) \rightarrow s(x,1)$.

Algorithm 2 – Algorithm to obtain a flow region in m transitions with n challenges

```
function GET_FLOW_REGION(m, n_challenges = 5, delta = 0)
    n ← n_challenges
    if (n_challenges > m) and is.odd(n_challenges) then
        n ← n − 1
    end if
    distr ← initialize_array(m, ⌊s/m⌋)
    rest ← s − m⌊s/m⌋
    if (rest > 0) then
        inv_sigma ← (n − rest)/2
        for i ← 0 to rest − 1 do
            distr[inv_sigma + i] ← distr[inv_sigma + i] + 1
        end for
    end if
    flow[0].min ← 0
    flow[0].max ← distr[0] − 1
    for i ← 1 to m − 1 do
        flow[i].min ← flow[i − 1].max + 1
        flow[i].max ← flow[i − 1].max + distr[i]
        if (n_challenges > m) and is.odd(n_challenges) then
            if is.odd(m) and (i = ⌊m/2⌋) then
                flow[i].max ← flow[i].max + 1
            end if
            if is.even(m) then
                if i = ⌊m/2⌋ − 1 then
                    flow[i].max ← flow[i] + 1
                end if
                if i = ⌊m/2⌋ then
                    flow[i].min ← flow[i] − 1
                end if
            end if
        end if
    end for
    for all r in flow do
        if (r.max = −1) then
            r.min ← −1
        else
            r.min ← r.min − delta
            r.max ← r.max + delta
        end if
    end for
    return flow
end function
```

The function "*get_flow_region*" described as the Algorithm 2 is summarized in a narrative form as: Calculates the number of levels that should be distributed for each transition of stage (lines 2-13). These values are calculated through a uniform distribution that tries to maintain the same number of levels in all stages. The stages located in the same distance of the mean stage should have the same number of levels. For example, the distribution of eight levels of challenge in five transitions is defined as the array $s = \{1,2,2,2,1\}$, where the second, third, and fourth transitions are set with two levels, it is $s(1) = s(2) = s(3) = 2$, whereas the first and fifth transitions are set with one level, it is $s(0) = s(4) = 1$. Finally, the transition located in the third transition is set with two levels, it is $s(2) = 2$. The steps that calculate these levels are as follows:

- The normalization for the number of challenges. This is done to avoid the non-uniform distribution that happens when this number is odd and it is greater than the number of transitions. For example, the distribution of nine levels among four transitions only can be done by setting one transition with three levels, and setting the rest of transitions with two levels. Therefore, the normalization for the levels of challenge is done by reducing the number of levels by one (lines 2-5). In the previous example, the distribution of nine levels into four transitions can be defined as the array $s = \{2,2,3,2\}$ before the normalization, and the distribution of these nine levels after the normalization is defined as the array $s = \{2,2,2,2\}$.

- After the normalization, the minimum number of challenge level for each stage is defined by the function "*initialize_array*" (line 6), which initializes an array of size m with the value. The remaining levels of challenge (line 7) are distributed according to the position "*inv_sigma*" (lines 10-12). The value "*inv_sigma*" is the result of dividing the number of free spaces after the distribution of the remaining challenge levels by two (line 11).

After determining the number of challenge levels that will be distributed for each transition (*distr*), the next step is to set the labels for the flow region that has no expected difference in the levels of challenge (lines 14-32). Thus, the process to define these labels consists in:

- To set the flow region for the first transition through the definition of the minimum challenge level with value zero (line 14), and the definition of the maximum challenge level with the number of challenge levels decreased by one (line 15).

- Setting the flow region for the rest of the transitions (lines 16-32). The minimum level of challenge is defined as the maximum challenge level of the previous transition increased by one (line 17), and the maximum challenge level is defined as the maximum challenge level of the previous transition increased by the number of challenge levels (line 18). For cases in which the normalization of levels has been done, the following two rules must be applied:

– If the number of transitions is odd, then the maximum challenge level is increased by one in the mid-transition (lines 20-22). Thus, the flow region for nine levels of challenge in five transitions is defined as the array $s = \{[0;0],[1;2],[3;5],[6;7],[8;8]\}$.

– If the number of transitions is even, then there are two mid-transitions: the first mid-transition is located in the position $\lfloor m/2 \rfloor - 1$, and the second mid-transition is located in the position $\lfloor m/2 \rfloor$. Next, the maximum challenge level is increased by one in the first mid-transition (lines 24-26). Finally, the minimum challenge level is decreased by one for the second mid-transition (lines 27-29). Thus, the flow region for nine challenge levels in four transitions is defined as the array $s = \{[0;1],[2;4],[4;6],[7;8]\}$.

Finally, the expected difference in level of challenge, defined as the parameter delta, is used to decrease and increase the minimum and maximum levels of challenge for each transition in the flow region (lines 33-40).

5.2.3 Benefits and Application of GMIF Model

Several factors must be considered during the learning design process, such as learning goals, pedagogical preferences, intervention timing, type of feedback, students' needs, available resources, and so on. The work of Koedinger, Booth and Klahr (2013) estimates that there is a poll of 330 (205 trillion) instructional choices that could be considered when designing a learning activity. Unfortunately, most designers and educators do not have enough knowledge/skills to cope with this huge number of instructional choices and select those choices that are the best fit for a particular situation. To provide help for the instructional designers in this process, the n-scale GMIF model provides an appropriate integration of instructional design with learning theories, models of learner's growth, and the three-channel flow model, in order to reduce the complexity of the learning design task. Specifically, the GIMF model can be used to foster flow experiences in theory-based learning scenarios.

Foster Flow Experiences in Theory-Based Learning Scenarios

To get students into the flow state and produce optimal learning experiences, one should initially consider:

- The student's initial stage and learning objectives (as final stage) in terms of knowledge acquisition and skills development (ANDERSON, 1982; RUMELHART; NORMAN, 1976);

- The learning path to be follow by the student based on theoretical justifications (ISOTANI *et al.*, 2010; ROMISZOWSKI, 1981); and

- The definition of the challenge level based on the three-channel flow model. Here it is necessary to select the necessary challenge level to keep the student in the flow state (CSIKSZENTMIHALYI, 2014; D'MELLO, 2012).

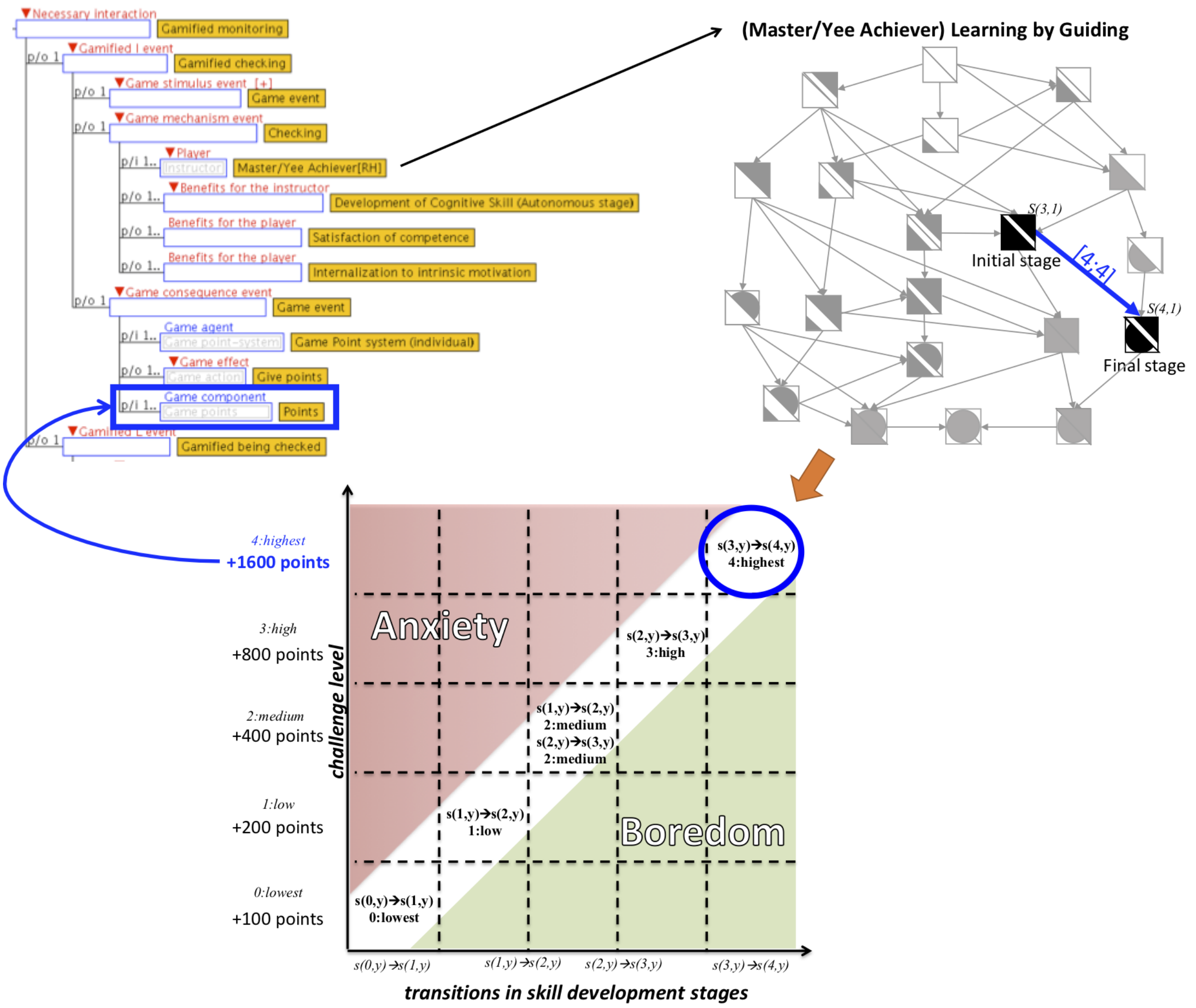
The GMIF model has been developed to support these steps. In the first step, the GMIF model provides a standard to describe and represent learning objectives as well as the learner's stage. Thus, the problem of sharing learning designs among people and computers is reduced. Accordingly, an instructional designer can indicate the initial stage of the student and select his/her learning objectives. Both correspond to stages in the GMIF model. After that, the designer can check manually or automatically (using learning design authoring tools) which learning strategy based on instructional/learning theories provides an adequate learning path that supports a learner in achieving the desired goals. In this situation, the GMIF model offers a visual representation as a sequence of arrows on the GMIF model that represent learning strategies and how they support the learner's growth process. Finally, to provide a flow experiences, the designer needs to define the level of challenge that is needed to maintain the student in the flow state. In this regard, the GMIF model will indicate the level of challenge that should be considered when creating tasks to alter the state of the student while keeping him/her motivated.

5.3 Application of GIMF Model for the Definition of Game Rewards in Gamified CL Scenarios

With the GMIF model detailed above, we can develop different functions in authoring tools of learning scenarios. A useful function developed by the author of this dissertation is the searching of proper learning objects that will favor and maintain the learner's flow in the learning scenario (CHALLCO *et al.*, 2016). Thus, in this function, an instructional designer firstly set the initial and goal stages of a student in a learning scenario using the graphical representation of the GMIF model. Next, each label for a difficulty level in the transition from the initial stage to the goal stage is used as a constraint to search learning objects from different repositories.

To demonstrate the usefulness of the GIMF model in the gamification of CL scenarios, the definition of game rewards to be promised and given by game agents in gamified instructional and learning events is presented here as an application in which ontological structures to represent gamified I_L events are used as information source. For accomplish this task, the instructional designer first set the initial and goal stages in the graphical representation of GIMF model using the information provided by the individual goal (*I-goal*) in the instructional and learning event. Then, the learning path from the initial stage to the goal stage is identified as the learning strategy employed by the participant, and the labels of challenge levels are calculated for the arrows in the learning path according to the number of challenges/levels that could have a game component. Finally, these labels can be used as constraints to set the game reward to be promised or given by the game agent to keep the participant in the flow state.

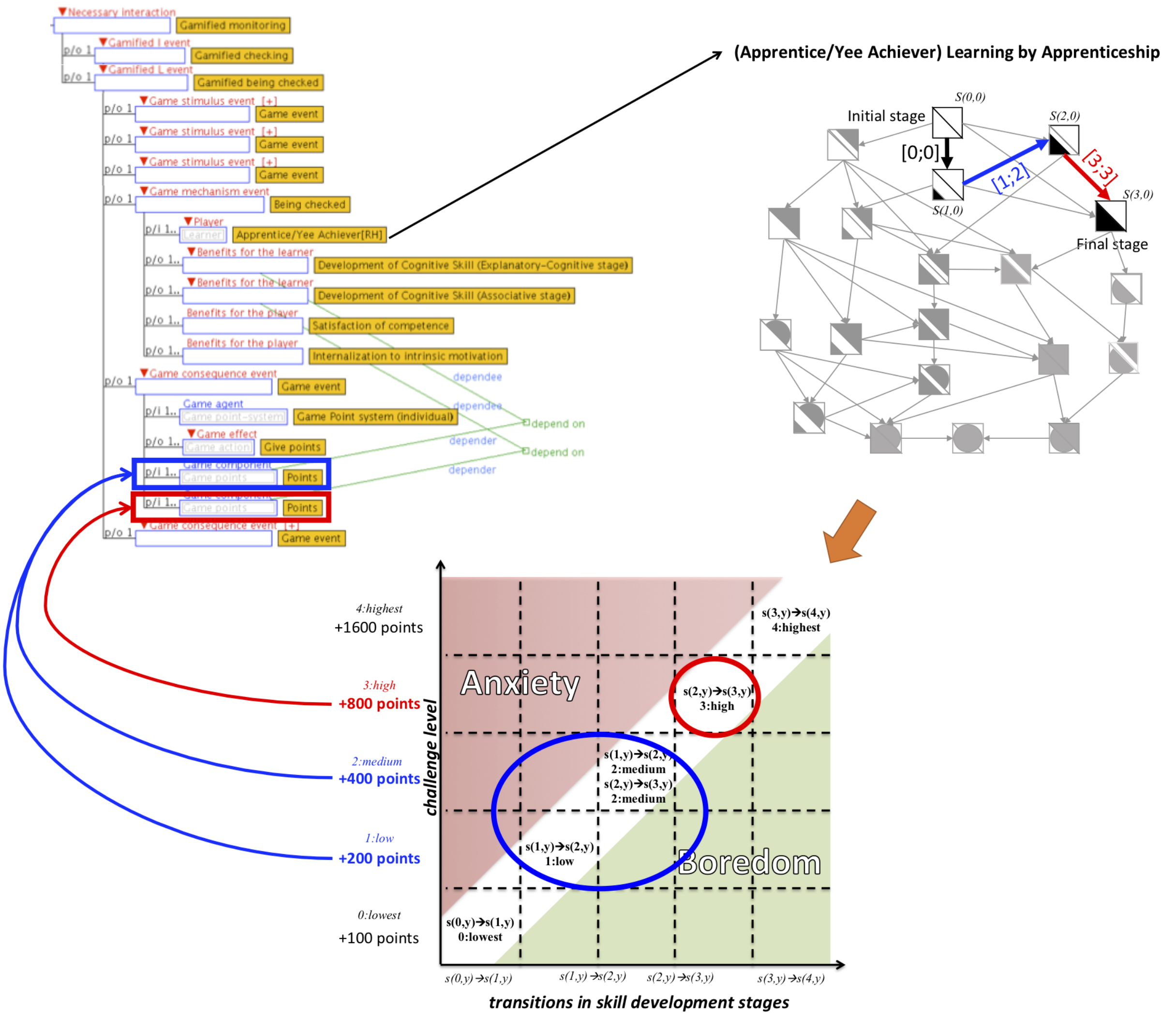
Figure 42 – Application of the GMIF model to set the game points to be given in the gamified instructional event "*Gamified Checking*" of the *Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*



Source: Elaborated by the author.

For the instance shown in Figure 42, 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 43 – 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 43 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 $s(1,0) \to s(2,0)$ 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

+400 points as the game rewards that will be given by the point-system in the game consequence event when the expected benefit for the *Apprentice/Yee Achiver* role holder is the *Development of Cognitive Skill (Exploratory-Cognitive stage)*. The label "$[3;3]$" in the transition $s(2,0) \rightarrow s(3,0)$ of GIMF model indicates that the challenge level to maintain the learner's flow state is 4:*high*. This challenge level corresponds to the game reward "*+800 points*" as the reward to be given by the point-system to maintain him/her in the flow state during the game consequence event when the expected benefit for the *Apprentice/Yee Achiever* role holder is the *Development of Cognitive Skill (Associative stage)*.

5.4 Concluding Remarks

Balancing the challenge level of elements in learning scenarios according to the current learner's ability favors the learner's flow state in those scenario. This balancing incorporates the flow theory in the instructional/learning design process by means of a theory-based model that integrates the learner's growth process and the three-channel flow model. This new model, called GMIF model (*Learner's **G**rowth **M**odel **I**mproved by **F**low Theory*), has been developed by labeling the LGM model (***L**earner's **G**rowth **M**odel*) with intervals that indicate the proper challenge levels to maintain the learner's flow state in the learning scenario.

An algorithm for labeling the LGM model with a n-scale of challenge levels, and then obtains the n-scale GMIF model, has also been proposed in this chapter. To demonstrate the usefulness of the n-scale GIMF model, an application to set the proper level of game rewards in gamified CL scenarios has been presented. This application has been illustrated providing support to define the points given by a point-system as game consequence events in gamified instructional and learning events. This algorithm and the n-scale GIMF model can be used in computer-based mechanisms and procedures to support the gamification of CL scenarios that favor the learner's flow. Furthermore, empirical studies were conducted to validate the application of GIMF model in the evaluation of the ontological engineering approach to gamify CL scenarios.

CHAPTER

6

COMPUTER-BASED MECHANISMS AND PROCEDURES TO GAMIFY COLLABORATIVE LEARNING SCENARIOS

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