UNIVERSIDADE DE SÃO PAULO
Instituto de Ciências Matemáticas e de Computação

Gamification of collaborative learning scenarios: an ontological engineering approach to deal with motivational problems in scripted collaborative learning

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Tese de Doutorado do Programa de Pós-Graduação em Ciências de Computação e Matemática Computacional (PPG-CCMC)

ICMC USP
SÃO CARLOS

SERVIÇO DE PÓS-GRADUAÇÃO DO ICMC-USP

Data de Depósito:

Assinatura: ______________________

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Doctoral dissertation submitted to the Institute of Mathematics and Computer Sciences – ICMC-USP, in partial fulfillment of the requirements for the degree of the Doctorate Program in Computer Science and Computational Mathematics. *FINAL VERSION*

Concentration Area: Computer Science and Computational Mathematics

Advisor: Prof. Dr. Seiji Isotani

USP – São Carlos
July 2018

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Gamificação de cenários de aprendizagem colaborativa: uma abordagem de engenharia de ontologias para lidar com problemas motivacionais na aprendizagem colaborativa com scripts

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. *VERSÃO REVISADA*

Área de Concentração: Ciências de Computação e Matemática Computacional

Orientadora: Prof. Dr. Seiji Isotani

USP – São Carlos
Julho de 2018

ABSTRACT

CHALLCO, G. C. **Gamification of collaborative learning scenarios: an ontological engineering approach to deal with motivational problems in scripted collaborative learning**. 2018. 96 p. Tese (Doutorado em Ciências – Ciências de Computação e Matemática Computacional) – Instituto de Ciências Matemáticas e de Computação, Universidade de São Paulo, São Carlos – SP, 2018.

Increase both students' motivation and learning outcomes in Collaborative Learning (CL) activities is a challenge that the Computer-Supported Collaborative Learning (CSCL) community has been addressing in the past last years. The use of CSCL scripts to structure and orchestrate the CL process has been shown to be effective to support meaningful interactions and better learning, but the scripted collaboration often does not motivate students to participate in the CL process, which makes more difficult the use of scripts over time in CL activities. To deal with the motivational problems, the researchers, educators and practitioners are now looking at gamification as a solution to motivate and engage students. However, the gamification is a complex task, requiring from instructional designers and practitioners, knowledge about game elements (such as leaderboards and point systems), game design (e.g. how to combine game elements) and their impact on motivation, engagement and learning. Moreover, the gamification is too context-dependent, requiring personalization for each participant and situation. Thus, to address these issues, an ontological engineering approach to gamify CL sessions has been proposed and conducted in this dissertation. In this approach, an ontology has been formalized to enable the systematic representation of knowledge extracted from theories and best practices related to gamification. In this ontology, the concepts, extracted from practices and theories related to gamification, and identified as relevant to deal with the motivational problem caused by the scripted collaboration, have been formalized as ontological structures to be used by computer-based mechanisms and procedures in intelligent-theory aware systems. These mechanisms and procedures with ontological structures aim to provide support to give advices and recommendations that will help instructional designers and practitioners to gamify CL sessions. To validate this approach, and to demonstrate its effectiveness and efficiency into deal with the motivational problems caused by the scripted collaboration, four empirical studies were conducted in real situations at the University of São Paulo with undergraduate Computer Science and Computer Engineering students. The results of the empirical studies demonstrated that, for CL activities where the CSCL scripts are used as a method to orchestrate and structure the CL process, the ontological engineering approach to gamify CL scenarios is an effective and efficient solution to deal with the motivational problems because the CL sessions obtained by this approach affected in a proper way the participants' motivation and learning outcomes.

Keywords: Ontologies, Gamification, Computer-Supported Collaborative Learning, Scripts,

Motivational Problem .

RESUMO

CHALLCO, G. C. **Gamificação de cenários de aprendizagem colaborativa: uma abordagem de engenharia de ontologias para lidar com problemas motivacionais na aprendizagem colaborativa com scripts**. 2018. 96 p. Tese (Doutorado em Ciências – Ciências de Computação e Matemática Computacional) – Instituto de Ciências Matemáticas e de Computação, Universidade de São Paulo, São Carlos – SP, 2018.

Aumentar a motivação e os resultados de aprendizagem dos estudantes nas atividades de aprendizagem colaborativa é um desafio que a comunidade de Aprendizagem Colaborativa com Suporte Computacional tem abordado nos últimos anos. O uso de scripts para estruturar e orquestrar o processo de aprendizagem colaborativa demonstrou ser eficaz para dar suporte as interações significativas e um melhor aprendizado, mas a colaboração com scripts muitas vezes não motiva os alunos a participar do processo de aprendizagem colaborativa, o que dificulta o uso de scripts ao longo do tempo em atividades de aprendizgem colaborativas. Para lidar com problemas de motivação, os pesquisadores, educadores e profissionais estão agora olhando a gamificação como uma solução para motivar e envolver os alunos. No entanto, a gamificação é uma tarefa complexa, exigindo de projetistas instrucionais e profissionais, conhecimento sobre elementos do jogo (e.g. leaderboards e sistemas de pontos), design de jogos (e.g. como combinar elementos do jogo) e seu impacto na motivação, engajamento e aprendizado. Além disso, a gamificação é muito dependente do contexto, exigindo personalização para cada participante e situação. Assim, para abordar esses problemas, uma abordagem de engenharia ontologias para gamificar sessões de aprendizagem colaborativa foi proposto e desenvolvida nesta dissertação. Nessa abordagem, uma ontologia foi formalizada para possibilitar a representação sistemática de conhecimentos extraídos de teorias e melhores práticas relacionadas à gamificação. Na ontologia, os conceitos, extraídos de práticas e teorias relacionadas à gamificação, e identificados como relevantes para lidar com o problema de motivação causado pela colaboração com scripts, foram formalizados como estruturas ontológicas a serem utilizadas por mecanismos e procedimentos informatizados em sistemas inteligentes cientes de teorias. Esses mecanismos e procedimentos com estruturas ontológicas visam fornecer suporte para dar conselhos e recomendações que ajudarão os projetistas instrucionais e profissionais a gamificar as sessões de aprendizagem colaborativa. Para validar a abordagem e demonstrar sua eficácia e eficiência em lidar com o problema de motivação causado pela colaboração com scripts, quatro estudos empíricos foram conduzidos em situações reais na Universidade de São Paulo com estudantes de graduação em Ciência da Computação e Engenharia da Computação. Os resultados dos estudos empíricos demonstraram que, para as atividades de aprendizagem colaborativa no que os scripts são usados como um método para orquestrar e estruturar o processo da aprendizagem colaborativa, a abordagem de engenharia ontológica para gamificar cenários de aprendizagem colaborativa é um eficaz e eficiente solução para lidar com o problema de motivação porque as sessões de aprendizagem colaborativa obtidas por essa abordagem afetaram de maneira adequada a motivação e os resultados de aprendizagem dos participantes.

Palavras-chave: Ontologias, Gamificação, Aprendizagem Colaborativa com Suporte Computacional, Scripts, Problema de Motivação .

CONTENTS

CHAPTER 1

INTRODUCTION

This chapter starts presenting the delimitations of the context and the research problem addressed in this PhD thesis dissertation (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 detailed in section 1.4. Finally, the chapter ends with the structure of this dissertation (section 1.5).

1.1 Context and Research Problem Delimitations

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). The Computer-Supported Collaborative Learning (CSCL) is the research field that studies how this technology should link the advanced in computer science with the pedagogical approaches of collaborative learning, and it has been proved an important research field to support the instructional-learning process (STAHL; KOSCHMANN; SUTHERS, 2006). Some of the most relevant benefits of the integration between computer sciences and collaborative learning are: to facilitate the sharing and distribution of knowledge among group members (LIPPONEN, 2002; NORDIN; KLOBAS, 2010), to help the monitoring and evaluation of CL process (Rodríguez-Triana *et al.*, 2018; CABALLÉ *et al.*, 2011), and to enhance the peer interactions and work in groups (WANG, 2014; ZHAO; GAO; YANG, 2018).

The CSCL technology is more beneficial for the students when there is an adequate design of the CL process, when there is a mechanism to support and orchestrate the ways in which the students should collaborate to achieve pedagogical benefits (DILLENBOURG, 2013; HEWITT, 2005; ISOTANI *et al.*, 2009). When there is not such support, students frequently fail to act or behave in a productive way. In a CL session, the participants need to know with whom they must work, they need to know what are their roles in the CL process, and they need to know the steps to accomplish their learning goals. Without this information, frequently, the participants will not adequately collaborate or leave to interact during the CL activities. Hence, several researchers propose the use of scripts to guide and orchestrate the collaboration in these activities (ALHARBI; ATHAUDA; CHIONG, 2014).

The scripted collaborative learning aims to engage the students in fruitful and significant interactions according to a design that has the purpose to attain a set of pedagogical objectives. Thereby, the research and practitioners of the CSCL community have proposed the use of scripts to support the well-thought-out design of the CL scenarios through computer-based systems (FISCHER *et al.*, 2013; KOBBE *et al.*, 2007). The CSCL scripts are the technology that indicates how the interactions among students will be orchestrated and structured 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 in the CL process. Despite of its benefits, there are situations in which the scripts may cause motivational problems. For example, when the students prefer to work individually or when they do not want to play the role assigned by the scripts, they may neglect their personal behavior to get the task completed without effort, and the lack of choice over the interactions may produce in them a sense of obligation. These issues cause troubles in the group dynamic - e.g. some students may dropout the CL activity, making superficial interactions - resulting in negative and widespread learning outcomes.

The motivational problems in scripted collabotive learning make more difficult the use of this technology over time. Less motivated students prefer to spend more time in other activities instead of participated in the collaborative learning and, as consequence, the achievement of contemplated learning outcomes becomes more difficult (CROOK, 2000; FALOUT; ELWOOD; HOOD, 2009; SCHOOR; BANNERT, 2011). In this sense, motivating learners in the entire CL process is important. However, the traditional instructional design practice often assumes that the motivation is a preliminary step that occurs outside to the learning process (CHAN; AHERN, 1999; KELLER, 1987). This assumption is based in which the good quality of learning materials and content-domain 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 motivation. To avoid this motivational problem known as demotivation, some researchers and practitioners currently propose the development and use of affec(FEIDAKIS *et al.*, 2014; FEIDAKIS *et al.*, 2014)tive feedback systems base(WOOLF *et al.*, 2009)d on emotion-aware systems and learning companions to motivate students along the entire learning process. These solutions assume that the students like the content-domain and that they have the desired to learn working in groups, so that the approach of using affective feedback systems does not motivate and engage students without the desire to learn or to work in groups.

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 working in groups. In this direction, several researchers and practitioners have pointed Gamification as a promising technology to deal with motivational problems in educational contexts (CHALLCO *et al.*, 2014; SEABORN; FELS, 2015; BORGES *et al.*, 2014). Gamification "*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. Through the introduction of game elements, such as points, rankings, competition, cooperation and so on, gamification intends to engage and motivate students who do not have the desire or interest in to learn the content-domain working in groups. According to (KAPP, 2012; KNUTAS *et al.*, 2014), when a learning process is gamified, the benefits of introduced game elements will strongly depend on how well these game elements will be applied, and how well they are linked with the pedagogical approaches employed in the learning process.

When CL scenarios are gamified to deal with the motivational problems that can occur in a scripted collaborative learning, the thesis author hypothesizes that the chances to achieve engagement and educational benefits will be increased if there is a proper connection between the game elements and the CL process. However, developing such well-though-out gamified CL scenario, hereinafter called gamified CL scenarios, is a non-trivial task. 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 from individual to individual, from situation to situation, and occasionally. Gamification depends of many factors such as the individual personality traits, preferences, and current student's emotions (NICHOLSON, 2015; PEDRO *et al.*, 2015) (e.g., a ranking of participation would motivate users who like competition but not users who want to customize their items and avatars). Also, the expected effects of the game elements vary according to the non-game context and the target behavior that is being gamified (DETERDING *et al.*, 2013; HEETER *et al.*, 2011) (e.g., gamifying a learning scenario to promote the signing-up is not the same thing as gamifying an interactive environment to maintain the student's 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, hereinafter referred to as the *knowledge from theories and practices of gamification*, is constituted by gamification practices, games design models and the theoretical psychological employed by researchers and practitioners to gamify different non-game contexts; and it lacks of a formal and common vocabulary, definitions, and representation to be easily applied. 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 representations of concepts and characteristics about how to gamify a non-game context. This fact hinders the creation of models/frameworks that formally represent the gamification and its application in a common understandable and shareable manner. To the best of the thesis author's knowledge, there is no one approach to represent the knowledge about how to gamify CL scenarios, and how through the gamification is possible to deal with motivational problems in a scripted collaborative learning.

Owed 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 used to orchestrate the CL process, it is necessary to personalize the gamification for each student and situation, so providing a tailored gamified CL scenario is necessary to achieve better benefits of gamification. Developing tailored gamified CL scenarios is a difficult and time-consuming task, so that a computational based-support to personalize the gamification is necessary and very helpful. In this direction, in the context of CSCL, there is only one interesting approach that proposes to personalize gamification based on individual preference profiles estimated from an interaction analysis by machine learning techniques (KNUTAS *et al.*, 2017; KNUTAS *et al.*, 2016; KNUTAS *et al.*, 2014). However, this solution is not oriented to deal with motivational problems in the scripted collaborative learning, its purpose is to increase the communication among the participants in any CL scenarios (not necessarily scripted). Furthermore, this solution does not provide a model to share theoretical knowledge of gamification obtained by its computational mechanisms and procedures to personalize the gamification. Solutions based on machine learning to personalize gamification require many data to support the personalization of gamification, and they may fall in an over-fitting or under-fitting problem with the data. A computational mechanism based only in machine learning techniques to personalize gamification will always lack of theoretical-justification to explain why a game element has been introduced in the non-game context, and why a certain configuration of game elements engages and motivates the students as participants of a CL activity to continue and adequately interact in the CL scenario.

For the reason exposed above, to deal with motivational problems in a scripted collaborative learning through the gamification, a computational support is essential to overcome the challenges and difficulties of gamification, a computational system with common and shareable structures to represent knowledge from practices and theories of gamification. In this direction, we have ontologies as the most advanced technology to support the representation of knowledge in a common understandable and shareable manner for computers and humans (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 delineate 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 provided by Internet, computational mechanisms and procedures for intelligent tools are developed to use the ontologies as a language to share the understandings and interpretations of *target world* - in this thesis dissertation, the target world is the gamification of CL scenario.

Employing ontologies to represent the knowledge from theories and practices of gamification, some interesting and practical results have been obtained by Dermeval *et al.* (2016), Karkar, Ja'am and Foufou (2016), Zouaq and Nkambou (2010). However, to the best of the thesis author knowledge, there is no one ontology that, from a philosophical perspective, gives support for the systematical representation of it knowledge and how to apply it in CL scenarios to deal with motivational problems. Therefore, the general research goal in this thesis dissertation refers to the definition of this ontology from a philosophical perspective.

1.2 Research Questions and Research Objectives

The research topic explored in this PhD thesis dissertation is addressed to answer the question: "*How to deal with motivational problems in scripted collaborative learning?*"

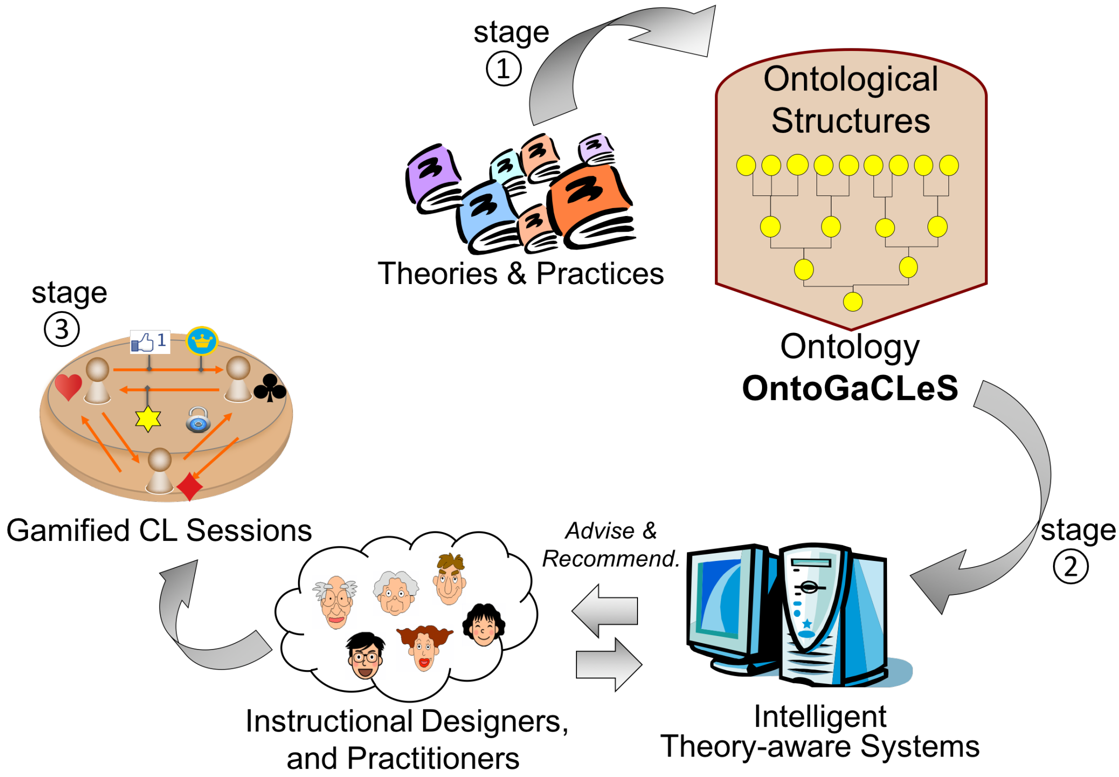
To answer this research question, the author of this thesis proposes the gamification of CL scenarios. However, as the previous section explained the gamification is too context dependent, so that, to obtain tailored gamified CL scenarios, intelligent tools are necessary to provide support in the personalization of gamification. In this sense, it is necessary a common way to represent the knowledge extracted from practices and theories of gamification because an adequate gamification of CL scenarios should rely on this theoretical knowledge. Thus, thesis author proposed the use of ontologies to represent the knowledge from theories and practices of gamification because ontologies have been consolidated as the technology in which computers and humans use a common language to build models/frameworks about the target world that is being represented. Thereby, the overarching research question (**RQ**) addressed in this thesis is:

"*How can gamification and ontologies be used to deal with motivational problems in scripted collaborative learning?*"

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

1. The first stage is: the formalization of the necessary knowledge about how to gamify CL scenarios for dealing with motivational problems in scripted collaborative learning 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 of gamification, the thesis author defines a set of ontological structures to enable the systematic formalization and representation of knowledge to gamify CL scenarios and its theoretical foundation.

Figure 1 – Ontological engineering approach to gamify CL scenarios



Source: Elaborated by the author.

2. The second stage is: the development of computational mechanisms and procedures whereby intelligent tools will provide support in the gamification of CL scenarios to deal with motivational problems in a scripted collaborative learning. Such support is given by the knowledge formalized in the ontology OntoGaCLeS during the first stage, so that the purpose for the computational mechanisms and procedures in intelligent tools is to use the ontological structures from this ontology to facilitate the tasks of instructional designer and practitioners, especially novice users, in the gamification of CL scenarios. These ontological structures contain the theoretical justification for the personalization of gamification, and they are used to obtain tailored gamified CL sessions adapted for each situation. These sessions are known as ontology-based CL sessions, and they are CL scenarios that have been gamified and instantiated at the most concrete level of CL scenarios in which the participants and the content-domain to be learned are well defined and it can be directly run in a learning environment.

3. The third stage is: the execution of empirical studies to understand the effects of ontology-based gamification on CL scenarios, and then, to validate the ontological engineering approach to gamify CL scenarios as a method to deal with motivational problems in scripted collaborative learning. This validation has 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 motivational problems.

Regarding to the formalization of knowledge about how to gamify CL scenarios for dealing with motivational problems in a scripted collaborative learning (Stage 1), the research questions answered by this dissertation are:

RQ1: the *Which concepts from theories and practices of gamification should be contemplated to deal with motivational problems in a scripted collaborative learning?*, and *How should these concepts be applied in the gamification of CL scenarios?*

RQ2: *What ontological structures are necessary to represent the concepts identified as relevant in the theories and practices of gamification to deal with motivational problems in scripted collaborative learning?*

Regarding the development of computational mechanisms and procedures whereby intelligent tools will provide support in the gamification of scenarios using the knowledge described in the ontology OntoGaCLeS (Stage 2), the research questions answered by this dissertation are:

RQ3: *What computational mechanisms and procedures are necessary in intelligent tools 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 to deal with motivational problems in a scripted collaborative learning?*

Regarding to the validation of the ontological engineering approach to gamify CL scenarios as a method to deal with motivational problems in scripted collaborative learning (Stage 3), the research questions answered by this dissertation are:

RQ4: *What are the effectiveness and efficiency of the ontological enginnering approach to gamify CL scenarios to deal with motivational problems in scripted collaborative learning?*

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 of gamification that should be taking into account to deal with motivational problems in scripted collaborative learning; and

RO2: To define the ontological structures to represent the concepts identified as relevant in the theories and practices of gamification to deal with motivational problems in scripted collaborative learning.

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

RO3: To identify and define the computational mechanisms and procedures that must be implemented by intelligent tools 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 motivational problems in a scripted collaborative learning.

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 validating the ontology engineering approach to gamify CL scenarios in reference to the effectiveness and efficiency to deal with the motivational problems in a scripted collaborative learning.

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

- To compare, validate or judge the theories and practices of gamification.
- To create, modify or extend the concepts described in the theories and practices of gamification.
- To create a generic and complete representation of all concepts described in the theories and practices of gamification. The thesis author concentrates only on the formalization of the minimal necessary concepts from these practices and theories to deal with the motivational problems in scripted collaborative learning.
- 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 consisted in four iterative phases: informational, propositional, analytical and evaluation.

Informational phase: In this phase, the thesis author identified the research problems and potential solutions 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. The thesis author performed this literature review emphasizing in the subjects of scripted collaborative learning, 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 20$^{\text{th}}$ 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 6$^{\text{th}}$ 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. The focus of this research is to study, design and implement 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 resulting from their involvement in various research projects about 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, ontological structures to represent the necessary concepts to gamify CL scenarios were identified and formalized in the ontology OntoGaCLeS. Prototypes of computational mechanisms and procedures to be used by intelligent tools to gamify CL scenario were developed for gathering instructional designers' opinions as early feedback of these systems. The tasks carried out in this phase correspond to activities extracted from the scientific (proposing theories or models) and engineering (proposing and developing solutions) research methods. These tasks were:

- The proposal of ontological structures 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 to represent the application of persuasive game design models in gamified CL scenarios and ontological models to apply persuasive game design strategies as a method for dealing with the motivational problems.
- The proposal of a computer-based model to support the representation of the learners' growth process and the principle of good balance between the perceived challenges and skills defined in the flow theory.
- The definition of a conceptual flow to gamify CL scenarios as a procedure to use the knowledge described in the ontology OntoGaCLeS, and the definition of a reference architecture based on this flow to build intelligent tools for dealing with motivational problems in a scripted collaborative learning.

Analytical phase: This phase consists into analyze and explores 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 activities 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 models to personalize the gamification of CL scenarios. This formalization is a case study 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 CL scenarios.
- The implementation of a computational mechanism (as a proof of concept) in which the knowledge encoding in the ontology 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 computational mechanism (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 data gathered through the tests and evaluations aimed to assess the contributions from different perspectives. The tasks carried out during this phase correspond to activities 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 as scientific articles in conferences and journals of 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 12th International Conference on Intelligent Tutoring Systems, ITS, 2014; "*An Ontology Engineering Approach to Gamify Collaborative Learning Scenarios*" published in the 20th 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 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 design strategies as a method for dealing with motivational problems in scripted collaborative learning. This evaluation was carried out by publishing these ontological structures and the ontological models obtained from them in the analytical phase 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 17th 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 26th Brazilian Symposium of Informatics in Education, SBIE, 2015; "*Gamification of Collaborative Learning Scenarios: Structuring Persuasive Strategies Using Game Elements and Ontologies*" published in the 1st 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 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 motivational problems in scripted collaborative learning. Such effectiveness was measured by comparing the participants' motivation and learning outcomes in the ontology-based CL sessions against the participants' motivation and learning outcomes in non-gamified CL sessions, and the percentage of participation by groups.

- The conduction of two full-scale empirical to evaluate the effectiveness of *the ontological engineering approach to gamify CL scenarios*. This effectiveness has been measured in the empirical studies by comparing the participants' motivation and learning outcomes in ontology-based gamified CL sessions against the participants' motivation and learning outcomes in non-gamified CL sessions.

- The conduction of a full-scale empirical study to evaluate the efficiency of *the ontological engineering approach to gamify CL scenarios* for dealing with motivational problems in scripted collaborative learning. Such efficiency was measured by comparing the participants' motivation and learning outcomes in ontology-based CL sessions against the participants' motivation and learning outcomes in CL sessions that were gamified without using the support given by the ontology OntoGaCLeS.

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 ontological engineering approach to gamify CL scenarios, understood from the viewpoint of an instructional designer as the gamifica-*

tion of CL scenarios in which the ontology OntoGaCLeS is used as support to personalize the gamification, constitutes an effective and efficient solution to deal with motivational problems."

Related to this thesis statement, the claimed contributions discussed throughout this PhD thesis dissertation are:

1. The identification of relevant concepts from the theories and practices of gamification to deal with motivational problems in scripted collaborative learning (RO1).

2. Ontological structures to represent: the concepts identified as relevant in theories and practices of gamification for dealing with motivational problems in scripted collaborative learning (RO2).

   a) Ontological structures 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.

   b) Ontological structures to represent: persuasive game design in CL scenarios, and ontological models to apply persuasive game design strategies as a method for dealing with the motivational problems in scripted collaborative learning.

3. A computer-based model to support the representation of the learners' growth process and the principle of good balance between challenges and abilities defined in the flow theory.

4. 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 intelligent tools that provide theoretical support for dealing with motivational problems in scripted collaborative learning (RO3).

5. Empirical evaluations of *the ontological engineering approach to gamify CL scenarios* in which, to validate the effectiveness and efficiency of this approach to deal with motivational problems, the participants' motivation and the learning outcomes in ontology-based gamified CL sessions are compared against the participants' motivation and the learning outcomes in non-gamified CL sessions and in CL sessions gamified without the support given by the ontology (RO4).

1.5 Structure of the Dissertation

This PhD thesis dissertation is structured in eight chapters that are described as follow:

Chapter 1: *Introduction*

Chapter 2: *General Background and Fundamental Concepts* contains the background related to the research problem addressed in this dissertation. An overview related to the fields of CSCL and scripted collaborative learning, gamification and ontology engineering are presented in the chapter. The motivational problems in scripted collaborative learning and the current approaches to deal with these problems are detailed in the chapter. The concepts that were identified as relevant in the theories and practices to deal with the motivational problems through gamification of CL scenarios are presented in the chapter.

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

Chapter 4: *Ontological Structures of Persuasive Game Design in CL Scenarios* describes the ontological structures proposed to apply persuasive game design models in CL scenarios. The chapter also describes the procedure employed by the thesis author to formalize an ontological model to apply gamification as persuasive technology in Cognitive Apprenticeship scenarios.

Chapter 5: *A Unify Modeling of Learners' Growth Process and Flow Theory* presents the computational model proposed to unify the modeling of the learners' growth process and the principle of good balance between the perceived challenges and skills described in the flow theory. This model has been used in the gamification of CL scenarios to define the reward levels given in the CL process as an attempt to maintain the flow states of participants.

Chapter 6: *Computer-based Mechanisms and Procedures to Gamify CL Scenarios* describes a flow proposed to gamify CL sessions based on the knowledge described in the ontology OntoGaCLeS. Based on this flow, a reference architecture by which intelligent tools to provide support in the gamification of CL scenarios for dealing with motivational problems is presented in the chapter. The chapter also describes the computational mechanisms and procedures developed based on 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 carried out in real situations to validate the effectiveness and efficiency of this approach to deal with motivational problems.

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

This chapter presents the general background and fundamental concepts related to the domain problem that is addressed in this thesis. At the first section (section 2.1), an overview of the CSCL field and scripted collaborative learning is presented to provide a comprehensive and elucidate accord about the research context. This section also describes in detail the motivational problems in scripted collaborative learning, as well as, the current approaches to deal with them. The section 2.2 presents an overview of gamification, and the theoretical foundation of this technology. Finally, **??** presents the fundamentals of ontologies and ontology engineering.

2.1 CSCL and Scripted Collaborative Learning

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

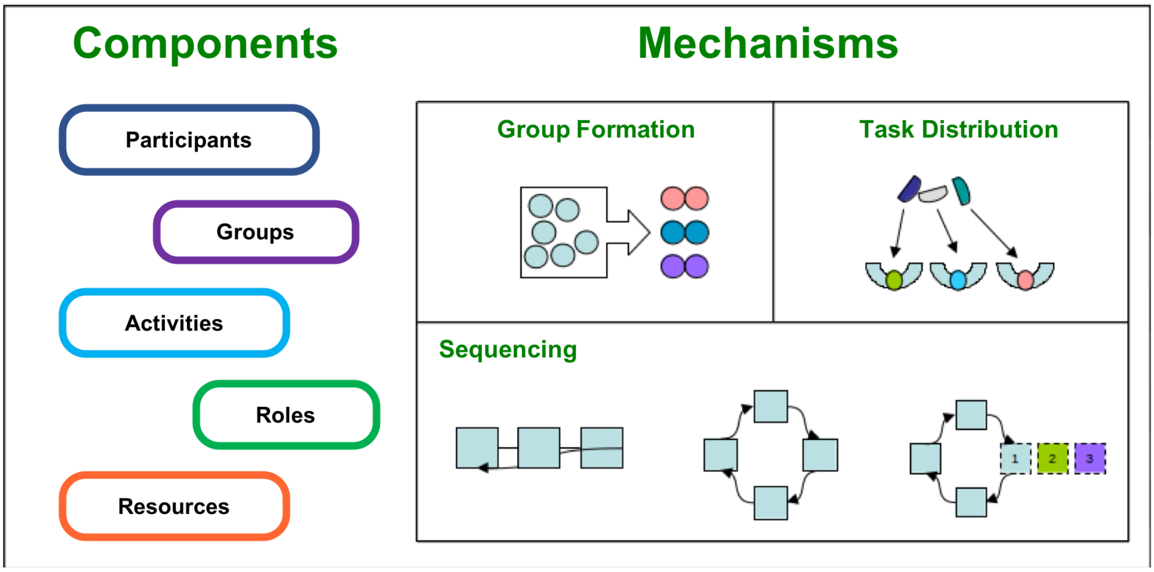
The general aim of CSCL field is to develop technologies to support or create situations in which two or more students learn together through the interaction among them (DILLENBOURG, 1999). In these situations, the learning outcomes are a consequence of students' interactions and how these interactions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

KOBBE; MALZAHN, 2007).

2.1.1 CSCL Scripts

CSCL scripts are the technology that describes the way of student should collaborate to achieve positive learning outcomes. These scripts basically structure and orchestrate the CL process to attain pedagogical objectives usually defined by an instructional design (DILLENBOURG; JERMANN, 2007). In this sense, the CSCL scripts are prescribed instructions that indicate how to facilitate the social and cognitive processes in group activities (DILLENBOURG, 2002). In order to narrow the number of elements used to describe the CSCL scripts, and provide a common and sharable description of CSCL scripts, Kobbe *et al.* (2007) propose a framework that is currently wide accepted by the community as the common specification to delineate the CSCL scripts using natural language. This framework formalizes the CSCL scripts as a set of components and mechanisms illustrate in Figure 2.

Figure 2 – Components and mechanisms of CSCL scripts



Source: Adapted from Fischer (2007).

The structural **components** of CSCL scripts are the participants, groups, activities, roles and resources. The component of *participants* delineates the participants, such as learners, monitors, and teachers. Although this description can be abstract or concrete and simple or complex, it is often presented in a simple manner with rules that indicate conditions to participate in the CL process. The component of *activities* delineates what will be performed by the participants in the CL process to attain the learning goals defined by the instructional designers. The component of *roles* delineates the privileges, obligations and expectations of participants in the CL process. The component of *groups* of participants defines by hierarchical structures how the students are grouped according to the participants' characteristics. The component of *resources* delineates the learning objects (e.g. content resources, material, and tools) that can be used by the participants during the CL process.

The **mechanisms** of CSCL scripts are the group formation, component distribution and sequencing. The mechanism of *group formation* consists in the specifications of how the participants will be distributed over the groups in the CL process. The mechanism of *task distribution* provides the specification about how the components of scripts are distributed over groups using the mapping of groups, activities, roles, and resources. The mechanism of *sequencing* consists in the definition of how the components and groups defined in scripts are distributed over time. In general, this sequencing delineates the interaction among the group members in the CL process.

Chart 1 – Components and mechanisms of social script

Structural components:	
Participants:	A number of participants that must be divisible by the number of case studies.
Groups:	Case groups
Activities:	(a) Applying theoretical concepts to the case study and constructing arguments (b) Critiquing initially scaffolder with prompts for eliciting clarification, identifying conflicting views and constructing counter-arguments
Roles:	*Analyst* and *Critic*
Resources:	Case studies (minimal number is three case studies)
Mechanisms:	
Group formation:	All participants are grouped by the number of case studies. Each participant becomes member of all case groups although with different roles in each. Each participant is the responsible analyst for one case study and critic for all other cases
Task distribution:	Each case group receives one case study, and the roles are distributed in a way that each participant assumes the role of analyst in one case group and the role of critic in all other case groups
Sequencing:	- the analyst writes an analysis of case study. (a) - wait for all case group analysts to be done, and writes a critique for the analysis of case study. (b) - wait for all case group critics to be done, and the analyst considers each critique and writes a reply to each. (a) - wait for all case group analysts to be done each critic in turn reads the reply and writes a second critique. (b) - wait for all case group critics to be done... the analyst considers all critiques and revises the analysis of case study (a)

Source: Adapted from Kobbe *et al.* (2007).

Chart 1 shows the description of the *social script* (WEINBERGER *et al.*, 2005) using the framework proposed by Kobbe *et al.* (2007). In this example, the CL scenarios orchestrated by the social script foster the acquisition of knowledge through case studies (*resources*) analyzed and reviewed by the student's groups. The students in each group are equal to the number of case studies, and the ideal number is three. In the first step of sequencing, each learner playing the *analysis* role writes down an analysis of case study, and then, he critiques the analyses made by other learners playing the *critic's* role. In the second step of sequencing, each learner revises his/her own analysis, taking into consideration the critiques received by the other learners in the case group.

Having the description of CSCL scripts only in natural language does not allow the computers programs to interpret them, and to run a CL scenario following the instructions indicated by the scripts without human intervention. Therefore, to represent the CSCL scripts in a computer readable manner, the IMS-Learning Design[1] (IMS-LD) specification has been adopted by different tools, such as (web)COLLAGE (Hernández-Leo *et al.*, 2006; Villasclaras-Fernández *et al.*, 2013), CIAN (MOLINA; REDONDO; ORTEGA, 2012), LeadFlow4LD (Palomino-Ramírez *et al.*, 2008), NUCLEO (SANCHO; Fuentes-Fernández; Fernández-Manjón, 2008), CoLearn (STYLIANAKIS *et al.*, 2013), CeLS (RONEN; Kohen-Vacs, 2009), and LAMS (Romero-Moreno; ORTEGA; TROYANO, 2007), as the language to describe CSCL scripts.

Despite the benefits that brings the use of the IMS-LD specification to represent CSCL scripts, several researchers have indicated that this language is insufficient to fully support the modeling of CSCL scripts (ALHARBI; ATHAUDA; CHIONG, 2014; CAEIRO; ANIDO; LLAMAS, 2003). Of course, the IMS-LD specification does not provide a full support for describing CSCL scripts, the IMS-LD has been developed as a neutral, generic and flexible educational modeling language to delineate a wide range of pedagogies approaches - the teaching strategies, pedagogical goals and their associated activities (KOPER, 2005). In this sense, to support the representation of CSCL scripts in a computer-readable manner, a wide variety of extensions on the IMS-LD elements have been proposed in by several researchers (Bote-Lorenzo *et al.*, 2004; LEO; PEREZ; DIMITRIADIS, 2004; MAGNISALIS; DEMETRIADIS, 2012a; MIAO *et al.*, 2005; Vega-Gorgojo *et al.*, 2005).

Instead to provide a simple computer-readable representation of CSCL scripts, the work of Isotani (2009), Isotani *et al.* (2013) proposes the formalization of CSCL scripts in a computer-understandable manner through ontologies. This solution consists in an ontology that makes the description of CSCL scripts as ontological structures to represent CL scenarios with a semantically-rich representation, allowing the explicit specification of learning goals, purposes, and other relevant information that cannot be represented using the IMS-LD specification, i.e., learning strategies, group goals, and interaction patters from learning theories. This formalization has been used by intelligent-theory aware systems to provide advice and recommendation for supporting the modeling of learners' development (INABA; IKEDA; MIZOGUCHI, 2003), the formation of effective groups (ISOTANI; MIZOGUCHI, 2008b), and the instructional design of CL activities (ISOTANI *et al.*, 2013).

2.1.1.1 Levels of Abstraction and Granularity of CSCL Scripts

CSCL scripts have different levels of abstraction and granularity in the description of CL scenarios (DILLENBOURG, 2002; DILLENBOURG; JERMANN, 2007; Villasclaras-

[1] URL: <http://www.imsglobal.org/learningdesign/>

Fernández *et al.*, 2009b). The classification of CSCL scripts in two dimension, according to the level of abstraction and to the level of granularity, gives them an enormous flexibility to be reused in the instructional design process of CL scenarios, and it also allows the use of multiple scripts to describe different aspects of CL scenario in separated scripts. The levels of abstraction classify the CSCL scripts according to the completeness of elements described by them, from the most abstract to the most concrete. The levels of granularity classify the CSCL scripts according to the aggregation level of elements described by them, from the most coarser grained to the finest grained.

According to Dillenbourg and Jermann (2007), a CSCL script is classified in one of the four levels of abstraction defined as follows as:

***Script Schemata*:** are CSCL scripts used to describe the core instructional design principles whereby is expected to trigger interactions among participants in the CL process. In this sense, these scripts are defined in a domain-content free didactic form, so that they can be used to describe patterns of CL. Examples of script schemata are the Jigsaw script (ARONSON, 1978; KORDAKI; SIEMPOS, 2010), conflict script (WEINBERGER *et al.*, 2005), and reciprocal script (KING, 2007). The *jigsaw* script describes a CL scenario in which the principle of interaction consists in the grouping and re-grouping of participants with complementary information to share their knowledge. The *conflict* script delineates a CL scenario to group learners with contradictory knowledge or opinions to instigate the discussion. The *reciprocal* script delineates a CL scenario that assigns alternate roles to the students for facilitating questioning and tutoring activities.

***Script Classes*:** are specialization of CSCL scripts schemata instantiated for a specific learning context. This specialization is not absolute complete, so that script classes are CSCL scripts with an independent content-domain and without specific student data. The script classes cover a range of scripts that describe variations of a prototype with particular details for a specific learning context of a script schemata to facilitate its adoption. These details are, for example, the number of participants, and the king of content (matter) that will be taught. In this sense, a script class is an instance of script schemata in which the elements of CSCL scripts are specified for a learning context. For instance, the Universanté Script (DILLENBOURG; JERMANN, 2007) is a script class based on Jigsaw schema designed to describe CL scenarios for learning contexts with different thematic groups and participants from different nations.

***Script Instances*:** are scripts in which the content-domain is specified for a particular situation. A script instance is more concrete than a script class, and it has been instantiated from a script schema or class to be reusable almost by teachers who only need to define participants' data. These scripts are more concrete that script classes, but they are independent in the particularities of students and learning environment.

***Script Sessions*:** are scripts in which the content-domain and participants data are specified to be directly executed in a learning environment. In this sense, these scripts detail the information of participants and content-domain in the most concrete level defining, for example, the students' names and the deadlines of activities. A CL scenario that is described by a script session is known as CL session, and when it is represented in a script session using a computer-readable formalization, it can be directly executed in a learning environment to orchestrate and conduct the CL process.

Different benefits from the use of script schemata and classes as patterns are obtained in the instructional design process of CL scenarios (ALHARBI; ATHAUDA; CHIONG, 2014; CHALLCO; BITTENCOURT; ISOTANI, 2016; MIAO *et al.*, 2005). During the design/authoring phase, repositories of script schemata and classes facilitate the sharing and reuse of these scripts in distributed learning environments (PRIETO *et al.*, 2013; PRIETO *et al.*, 2014). The structures of script schemata and classes are used as templates to create new script schemata and classes (Andreas Harrer; Ulrch Hoppe, 2007; RONEN; Kohen-Vacs, 2009).

During the instantiation/production phase, script schemata and classes provide advice and recommendation that help the CL practitioners to instantiate these scripts and to obtain CL sessions (MAGNISALIS; DEMETRIADIS, 2012b; PRIETO *et al.*, 2011; Alario-Hoyos *et al.*, 2013). Script schemata and classes facilitate the generation of computer-interpretable scripts, and they provide information to support the search of applicable learning material and tools for the CL scenario (Bote-Lorenzo *et al.*, 2004; ISOTANI; MIZOGUCHI, 2008b; Vega-Gorgojo *et al.*, 2005). The script schemata and classes indicate recommendations about how to bind individuals in groups and roles according to the knowledge described in these scripts (ISOTANI *et al.*, 2013; Villasclaras-Fernández *et al.*, 2009a).

Regarding to the level of granularity (FISCHER *et al.*, 2013), the CSCL scripts can be classified in macro-scripts and micro-scripts.

***Macro-scripts*:** are CSCL scripts that basically describe the CL process in a courser-grained level without detailing the specific interactions among participants. A macro-script describes how to attain a set of pedagogical objective indicating the sequencing of individual and group activities that must be followed by participants. Thus, for example, in the Jigsaw macro-script, to promotes the individual accountability and positive interdependence, the sequencing of activities consists in three activities: an individual activity, expert group activity, and jigsaw group activity. In the individual activity, each student studies a particular part of a whole problem. In the expert group, the students of different groups that study the same part of the whole problem meets together for exchanging ideas. At last activity, students of each jigsaw group meet to contribute with their expertise to solve the whole problem.

***Micro-scripts*:** are CSCL scripts that describe the CL process in a fine-grained level (WEINBERGER; FISCHER; STEGMANN, 2005). A micro-script basically indicates the dialogues that must happen among student to achieve the pedagogical objectives, and they are intended to describe the communication model between participants. Thus, to facilitate the negotiation and elaboration of a domain concepts, Weinberger *et al.* (2005) describe a micro-scripts for on-line peer discussion using a sequence of sentence openers (e.g. "my proposal for an adjustment of the analysis is...") that prompted learners to contribute with the discussion and critique one another's contributions.

As can be noticed above, CSCL macro-scripts and micro-scripts have a hierarchical relationship to describe the CL process. The micro-scripts delineate the communication process in a CL activity (WEINBERGER; FISCHER; STEGMANN, 2005), whereas the macro-scripts delineate groups, roles, and flow of CL activities (DILLENBOURG; HONG, 2008). Despite this explicit hierarchical relationship, there are few models and tools in which all the elements of macro-scripts and micro-scripts are combined to support the design of CL scenarios (ALHARBI; ATHAUDA; CHIONG, 2014; CHALLCO; BITTENCOURT; ISOTANI, 2016). Hernandez-Leo *et al.* (2006) propose a hierarchical model in which schemata and classes of macro-scripts and micro-scripts are used as templates to generate scripts. To support the automatic generation of unit of learning, the hierarchical relationships of macro-scripts and micro-scripts are represented as hierarchical task networks in the work of Challco *et al.* (2014a).

In the CL ontology (ISOTANI *et al.*, 2009), and therefore in the ontology OntoGaCLeS proposed in this thesis, the hierarchical relationship between the macro-scripts and micro-scripts is not explicitly described as a direct link between macro-scripts and micro-scripts. The hierarchical relationship of these scripts is implicitly described as part of the ontological structures to represent events and processes proposed by Galton and Mizoguchi (2009). Based on this conceptualization in which an event can be constituted by many distinct sub-events to describe a process, the hierarchical relationship of CSCL macro-scrips and micro-scripts can be extracted from the events used to describe the CL process.

2.1.2 Motivational Problems in the Scripted Collaborative Learning

In this PhD thesis dissertation, "*the motivational problems in scripted collaborative learning*" should be interpreted as the negative effects caused on the participants' motivation using CSCL scripts to orchestrate and structure the CL process.

Motivation is the psychological process that prompts a person to act in a certain way (MITCHELL; DANIELS, 2003), so it is a critical factor that influences the cognitive learning process (DECI; RYAN, 1985). Indeed, better learning outcomes are associated with the motivation of participants who demonstrate better curiosity, persistence, and performance for the learning activities (DECI; RYAN, 1985; Serrano-Cámara *et al.*, 2014). In fact, high levels of motivation for the participants of a CL scenario are associated with the improvement of learning outcomes achieved by them (CÁMARA; VELASCO; Velázquez-Iturbide, 2012; Serrano-Cámara *et al.*, 2014). Indeed, motivation affects the enjoyment and perception of team members' contributions with the implication that the participants who interact with interest in the CL process add value to their education so that they will experience higher-level learning outcomes (GOMEZ; WU; PASSERINI, 2010). In this sense, avoiding motivational problems is essential to entice the students to have a better participation in a CL process and to complete it.

By motivational problems, this thesis explicitly refers to the lack of motivation and the demotivation that the participants can experienced during a scripted collaborative learning. The lack of motivation, also known as "*amotivation*" (DECI; RYAN, 2010), occurs when there is an absence of motivation to behave or act, whereas the demotivation is the reduction or loss of motivation in behavioral intentions or in ongoing actions. The difference among the motivational problems can be understood, by the following example: Daniel does not want to participate in the CL activity when the group members are divided into two groups, one group with the more able ones and other group with the less able, and he is classified in the less able group. On the other hand, Gaby loses her desired to participate in a CL activity when she does not understand the instructions given by the teacher during the CL process and these instructions were given in an impatient or rude manner. Therefore, Daniel is an amotivated student who dislikes to be among the less able group, whereas Gaby is a demotivated student who once was motivated but for some reason she lost her initial desired or interest.

2.1.2.1 Amotivation and Demotivation

Amotivation, as was defined by Deci and Ryan (1985), refers to the relative absence of motivation caused by individual feelings of incompetence and helplessness when an individual faced with an activity. Indeed, a CL activity that occurs within participants having inability to master the collaboration becomes an amotivating situation. In this sense, the amotivation to participate in a scripted collaborative learning is to be understood hereinafter as a problem caused by general outcome expectations of CL process that is unrealistic. Thus, for example, when a participant conjectures that the use of CSCL scripts in the CL activity will force him/her to follow an unwilling sequence of interactions, he/she is an amotivated learner because he/she has the sensation of obligation, and he does not like to feel forced without being able to make his/her own decisions. The amotivation in a scripted collaborative learning can also occur if the participants have a lack of interests in the content-domain because they do not see or do not know why is important to learn about the subject under study. Also, the preference of participants to work individually instead of work in group has been observed as a factor that causes amotivation by Barros (2011). In this study, he identified that some students were not motivated to participate in a CL process because they felt that the teamwork is an obligation imposed by the teacher, showing difficulties in achieving their own goals, and demonstrating their boredom.

Demotivation is the psychological process defined as counterpart of motivation. It means that the demotivation is a process that decreases the learners' energy to move to achieve a goal. This process can lead to a general amotivation regarding the CL activity in which the motives to participate in a CL process cease to exist.

Dörnyei and Ushioda (2014) defines demotivation as specific external forces that reduce or diminish the motivational basis of a behavioral intention or an ongoing action. Based on this conceptualization and focused on external forces, the participants feel stressed and loss their initial motivation to work collaboratively, when they feel a lack of choice over the interactions of the CSCL script during the execution of CL scenario instantiated from it (ISOTANI, 2009). Over-scripting the CL process can also cause demotivation when the participants have difficulties to adapt to perform structured tasks, in specially, for highly coercive scripts in which the mechanism of sequencing indicates interactions in a very detailed and inflexible way (DILLENBOURG, 2002). The high level of coercion of this type of scripting collaboration forces the participants to have independent and exploratory thinking causing demotivation in participants who enjoy and prioritize their own individual decisions. Finally, as was pointed out by Schmitt and Weinberger (2018), another external force that causes the demotivation is the execution of scripted collaborative learning for an over extended time or over many CL activities.

The problem with the definition of demotivation proposed by Dörnyei and Ushioda (2014) is that it does not cover completely all factors that cause the loss of motivation. In this sense, the internal factors such as the participants' negative attitudes to a CL activity and the lack of self-confidence, factors relevant to the CL process, are not contemplated by them. This thesis considers both factors (internal and external) as source of demotivation for a scripted collaborative learning.

In summary, in the context of a scripted collaborative learning, a demotivated student/participant refers to someone who was once motivated but lost his or her initial motivation for some reason, and an amotivated student/participant refers to someone in whom there is no interest or commitment to participate in the scripted collaborative learning.

2.1.2.2 Effects of Motivational Problems on the scripted collaborative learning

Motivational problems of participants in a scripted collaborative learning degrade the dynamic of group members. For example, Wu *et al.* (2014) observed that, when Wiki systems are used to support the collaboration of participants in a CL process and there is no an effective mechanism in these systems to indicate task conflicts, there is low level of participation caused by the lack of motivation. The participation level was also indicated as factor affected by the lack of motivation by Mazzolini and Maddison (2003), and Hämäläinen (2008), Papadopoulos, Demetriadis and Stamelos (2009) indicate that students frequently drop out CL activities as consequence of the lack of motivation to work in groups. In relation to the demotivated, studies of Hart (2012), Grau-Valldosera and Minguillón (2014), Hartnett, George and Dron (2011) have shown the relation of motivational problems with the low level of persistence and high degree of dropout for CL activities. The dropping out of the CL process by motivational problems frequently causes that other learners are demotivated dropping out the scripted collaborative learning at mid term (HART, 2012; DILLENBOURG, 2013). Weinberger *et al.* (2005) indicated that the superficial interactions on scripted collaborative learning are the consequence of motivational problems.

Negative learning outcomes in peer-moderated discussions are indicated as consequences of the degradation of group dynamic by Xie and Ke (2009), Hewitt (2005). In these discussions, moderators plays the role of CSCL script by orchestrating and conducting the collaboration. Xie and Ke (2009) observed that the lack of motivation caused low level of participation, and by consequence of it, the knowledge elaboration and transfer were reduced. The lower level of participation was also indicated as factor that causes insufficient peer referencing in the peer-discussions (HEWITT, 2005).

Löfström and Nevgi (2007) indicated that the lack of motivation is one of the reasons for not participating in a CL process. Although no significant negative relationships in CL sessions were found between contributions to discourse and lack of motivation by Rienties *et al.* (2009), the study of Rienties *et al.* (2009) indicates that highly intrinsically motivated students in these session become central and prominent contributors to cognitive discourse.

Similar to the research works of Rummel and Spada (2007), Weinberger, Stegmann and Fischer (2010), this thesis dissertation argues that the scripted collaborative learning may cause motivational problems and reluctance towards a scripted collaborative learning based on the self-determination theory (DECI; RYAN, 2010) as a central element to delineate motivation. Depending of the individual characteristics of participants, they would suffer motivational problems to uphold their efforts, e.g., when students do not have an optimal fit between the external scripts (guidelines provided by the system that specifies the sequencing) and the internal script (low-structure script in the mind of students), and the external script provides scaffolds that guide procedures for which internal scripts are already represented by the learner or where a learner might even hold more effective or efficient internal script, the performance of the learner will decrease (STEGMANN *et al.*, 2011). In the same direction, negative effects on the participants' motivation have been pointed out by many researchers who have successfully applied CSCL scripts to enhance and mediate the CL process. For example, Brehm (1966) proved that, for some students, overlaying scripting produces reactance, and the work ofKollar, Fischer and Slotta (2005) indicate that the lost of motivation occurs when there is an overlaying of scripting. It indicates that, when the scripted collaborative learning is over extended for a long time and over many collaborative sessions as was shown in the studies of Hron *et al.* (1997), Schmitt and Weinberger (2018), there is more probability that the motivational problems will occur.

2.1.3 Approaches for Dealing with Motivational Problems in a scripted collaborative learning

Nowadays, to the best of the knowledge of the thesis author, there is no one specific approach to deal with motivation problems in a scripted collaborative learning. However, there are several approaches to motivate and engage the students in different learning situations (HARDRÉ, 2003; REIGELUTH; KRATHWOHL; Carr-Chellman, 1983; SPITZER, 1996). These approaches refer hereinafter as "*traditional approaches*," and, when they are applied in scripted collaborative learning to deal with motivational problems, they are classified as: Instructional design models that focus on motivational theories, and Affective feedback systems.

2.1.3.1 Instructional Design Models that Focus on Motivation

Instructional design models are basically guidelines to develop and orchestrate learning experiences to achieve instructional goals. They are defined as a collection of activities to plan, develop, evaluate and manage events and environments that are intended to facilitate the learning (SPECTOR; OHRAZDA, 2004). Thus, these models intend to prescribe the better way in which instructional/learning activities, content, activities and resources should be developed to provide effective and efficient learning. To obtain these instructional/learning material and environments, the guidelines in these models are based on instructional/learning theories. Instructional/learning theories describe "*how to better help the people to learn*" (instructional theory) and the "*ways that theorists believe that the people learn*" (learning «Use Collegiate Phrase: theory» theory).

In addition to instructional/learning theories, theories of motivation are covered by *instructional design models that focus on motivation*. In such models, motivation is seen as the factor that determines the intensity, attention, effort and persistence the learners put to complete their learning processes. The guidelines in these instructional design models encompass strategies, principles, and suggestions to raise and maintain the learners' motivation to learn based on theories of motivation. Thus, some of the instructional design models considered as model that focus on motivation by the author of this thesis are: The *ARCS model* proposed by Keller (2009), the *Time Continuum model* proposed by Wlodkowski and Ginsberg (2017), the *Taxonomy of Intrinsic Motivations for Learning* proposed by Malone and Lepper (1987)

In the instructional design models mentioned above, the motivation is assumed as a shared responsibility for the educational staff (instructional designers and teachers) and participants of CL process (students). Thereby, taking into account the participants' motivation is essential in the development of instructional/learning materials or environments. However, in the instructional design models, motivating learners toward a learning process does not occur during the the instructional/learning process (execution phase). The strategies, principles and suggestions given as guidelines in these models are used outside of this process. In this sense, when the instructional designers frequently use the guidelines of instructional design models, they frequently employ an one-size-fits-all approach, they ignore the fact that the participants' motivations vary occasionally, in amounts and in types, and from individual to individual. Furthermore, these instructional design models are used by the instructional designers, they take the assumption that the content-domain by itself is compelling and interesting for everyone. Making this assumption is dangerous because there will be always some content-domains that the participants of CL process will like and other content-domains that they dislike. Also, some students will prefer to study individually rather than to learn collaboratively or working in group.

By the reasons exposed above, the use of instructional design models that focus on motivation is a method to deal with motivational problems in a scripted collaborative learning. However, this solution makes only the content-domain and the instructional/learning process more appealing and engaging for the participants that have the desired to learn the content-domain. It means that, even if the instructional/learning material and processes are adapted for each individual, the participants without interest in the content-domain or the participants who dislike to work in group will not adequately complete the instructions indicated by the CSCL script.

2.1.3.2 Affective Feedback Systems

In psychology, the experiences of feeling and emotions are defined as affect (HOGG; ABRAMS, 2007), so that affective states are constructors used to delineate these experiences as emotional valence, arousal and motivational intensity (Harmon-Jones; GABLE; PRICE, 2013). Emotional valence refers to the subjective evaluation of an experienced state based on emotion's consequences and emotion-eliciting circumstances (Harmon-Jones *et al.*, 2011). In others words, an emotion is the cognitive interpretation of affection that is characterized by an intense mental activity and a high degree of pleasure or displeasure (CABANAC, 2002). Arousal is the physiological and psychological state of being awoken or of sense organs stimulated to a point of perception (Wikipedia, 2018; dos Santos *et al.*, 2018). Motivation intensity refers to the intensity that prompts a person to act, and, in this context, this is considered the impulsion degree that an individual puts to move away or toward some affective state.

As the affective states influence the motivation intensity of an individual, the regulation of affective states in a scripted collaborative learning can be used as a method to deal with motivational problems. To accomplish this regulation, it is necessary to detect, represent and express affective states in computational systems because the affective states vary from individual to individual and from situation to situation and occasionally. In this sense, computational systems should be used to recognize the affective states of participants through the identification of their emotions, moods and individual personality traits. Currently, there are plenty computational systems and researches that focus on the identification of affective states based on facial expressions, emotional speeches, physiological signals and interactions with the environments and/or computational systems (PICARD, 2000; TAO; TAN, 2005; WU; HUANG; HWANG, 2016; REIS *et al.*, 2018). Having this information, affective feedbacks can be given for the participants involved in the CL process. In this context, these feedbacks involve, not only the affective states inferred from the human-machine interactions, but also the affective stated inferred from student-student interactions. Thus, affective feedbacks are signals that indicates the current affective states of participants during the CL process, and despite of the levels of skill development and knowledge acquisition, these feedbacks provide positive or negative regulations to encourage the participants to continue or to change their ways of participation. These regulations are frequently provided by virtual agents or learning companions, and they are given in form of dialogues, but they can also include musics, animations and other ways of communication. Such regulations are *motivational dialog*ues because their purpose is to affect the participants' motivations - more specifically, they affect the motivational intensity through the regulation of affective states as was explained at the begin of this subsection.

Computational systems that behave and act according to the description presented in the previous paragraph are considered by the thesis author as *Affective feedback systems*, and they are frequently based on *emotional awareness systems*[2] to identify and engender the regulation of affective states during the CL process. Thus, for example, in the intelligent tutoring system "*Guru*" (OLNEY *et al.*, 2012), to deal with the demotivation occurred during collaborative lectures, D'Mello *et al.* (2012) implemented an affective feedback system that intends to motivate and engage the refocusing of participants' attention based on textual dialogues. These motivational dialogues are given by the system "*Guru*" when the affective states of boredom, disengagement and zoning-out are identified by the monitoring of participants' eye-gaze patterns (emotional awareness system). Tian *et al.* (2014) built an emotional awareness system that identifies the learners' emotions through the natural language process of Chinese textual interactions. Then, this system was used to support emotional-regulation recommendations in an active learning strategy where two learners interact playing the role of speaker and listener. In this scenario, the listener receives message send by the speaker with advices to regulate the speaker's emotions when the emotional-awareness system identifies boredom, frustration or fury. The advices are obtained by case-base reasoning during the learning activities. Finally, as example of affective feedback systems, a CC-LR (Collaboratige Complex Learning Resource) developed by Caballé *et al.* (2014) provides affective feedbacks to the participants of CL sessions in form of empathic dialogues based on fuzzy rules. In this learning system, *emotcontrol* (FEIDAKIS *et al.*, 2014; FEIDAKIS *et al.*, 2013) is used as emotional-awareness system in which several visualizations of individual and group affective states are provided for both the group members and instructor.

The use of affective feedback systems seems as an effective method to deal with motivational problems in a scripted collaborative learning. More specifically, this solution intends to avoid the demotivation (disengagement) of participants during the CL process. However, the participants' intrinsic motivation is only evoked by the motivational dialogues in the current affective feedback systems. When motivation arises from inside an individual, it is known as

[2] *emotional-aware* means be aware of the own or other participants' emotions and feelings

intrinsic motivation, and it involves the engagement to participate in the CL process by an own personal desire to learn. Essentially, the motivational dialogues in affective feedback systems are oriented to maintain the intrinsic motivation of participants with messages such as: "*Please, pay attention in the example*," "You might want to focus on me to understand the change," and "*Let's keep going*." As can be appreciated on these messages, they are pure related to the learning process by itself or focused on shown the advantages of exploring and learning new things. Therefore, the affective feedback systems as well as the instructional design models do not adequately work in CL scenarios where people simply have no internal desire to learn or when people do not want to work in group.

2.2 Gamification

By looking at whether motivation comes from, in addition to the intrinsic motivation, there is the extrinsic motivation that comes from outside of an individual. While the intrinsic motivation comes from the participants' desired to learn, the extrinsic motivation comes from the desired to avoid negative consequences (e.g. punishment, bad grades) or to obtain some external thing (e.g. tangible reward, approval from teacher/parents). Thus, to evoke the extrinsic motivation of participants, external rewards or punishments can be introduce in the CL process to raise the interest of participants in doing something when they see the working in group as an unpleasing situation or when they have no interest in the content-domain or when do not have the desire to learn. Although these rewards or punishments are extrinsic motivators, when they are properly used to make that the learners acquire new knowledge and develop new skills, they may produce in some learners a satisfaction for these accomplishments becoming then these learners more intrinsic motivate to learn in a scripted collaborative learning. Finally, these rewards and punishments can also be perceived by the learners as feedbacks, allowing the students known their performances in the CL process.

This section presents and details the theoretical foundation of a novelty approach known as Gamification in which game elements are used as extrinsic motivators to engage people to carried out a work, task or activity in which they have no internal interest. This approach also has the advantage that when the game elements are properly used, it would be a helpful tool to enhance the intrinsic motivation of participants.

In this section, before to detail what is gamification and to summarize its theoretical foundation, the differences between games, game elements and gameplay are briefly clarified. The related works of gamification in the context of CL and other educational contexts are also briefly summarized in this section. Furthermore, the rational reasons that justify the use of gamification as method to deal with motivational problems in a scripted collaborative learning are detailed.

CHAPTER

3

ONTOLOGICAL STRUCTURES TO PERSONALIZE THE GAMIFICATION IN COLLABORATIVE LEARNING SCENARIOS

This chapter presents the formalization of ontological structures proposed by the author of this thesis dissertation to represent gamified CL scenarios. These ontological structures allow us to systematically represent knowledge extracted from the player types models and needs-based theories of motivation to deal with motivation problems in scripted collaborative learning. This knowledge corresponds to concepts identified as relevant to solve the context-dependency of gamification based on the individual user characteristics, so that the ontological structures delineated 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 the 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.*, 2014b).

- "*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 formalizes the agreement in the negotiation process for group formation as ontological structures to 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 for the participants 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).

To provide theoretical and pedagogical justification in the group formation, 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, 2008a), 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 3 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*).

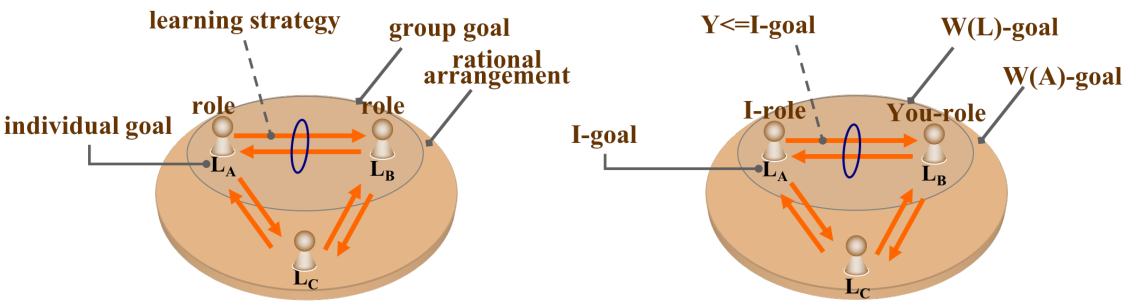
You-role is the CL role played by the participant (*You*) who is interacting with the participant in focus (*I*).

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

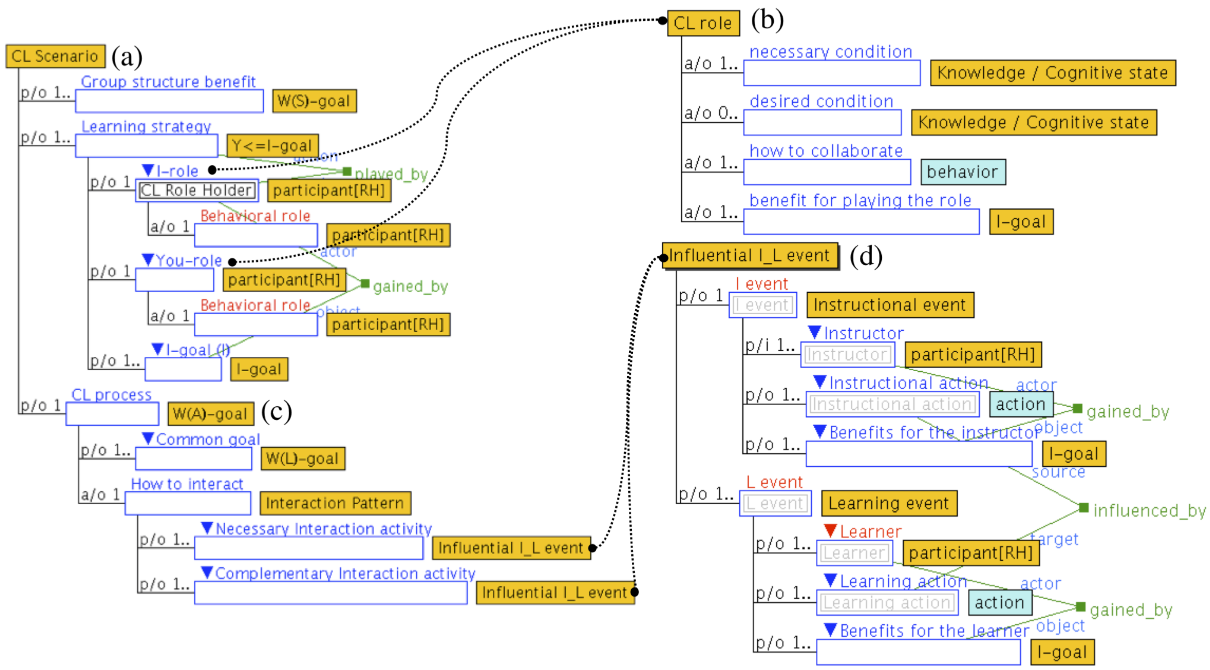


Source: Isotani (2009).

To express the relationship of concepts delineated above, the CL Ontology employs the ontological structures shown in Figure 4 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 4 – 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*) is 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*).

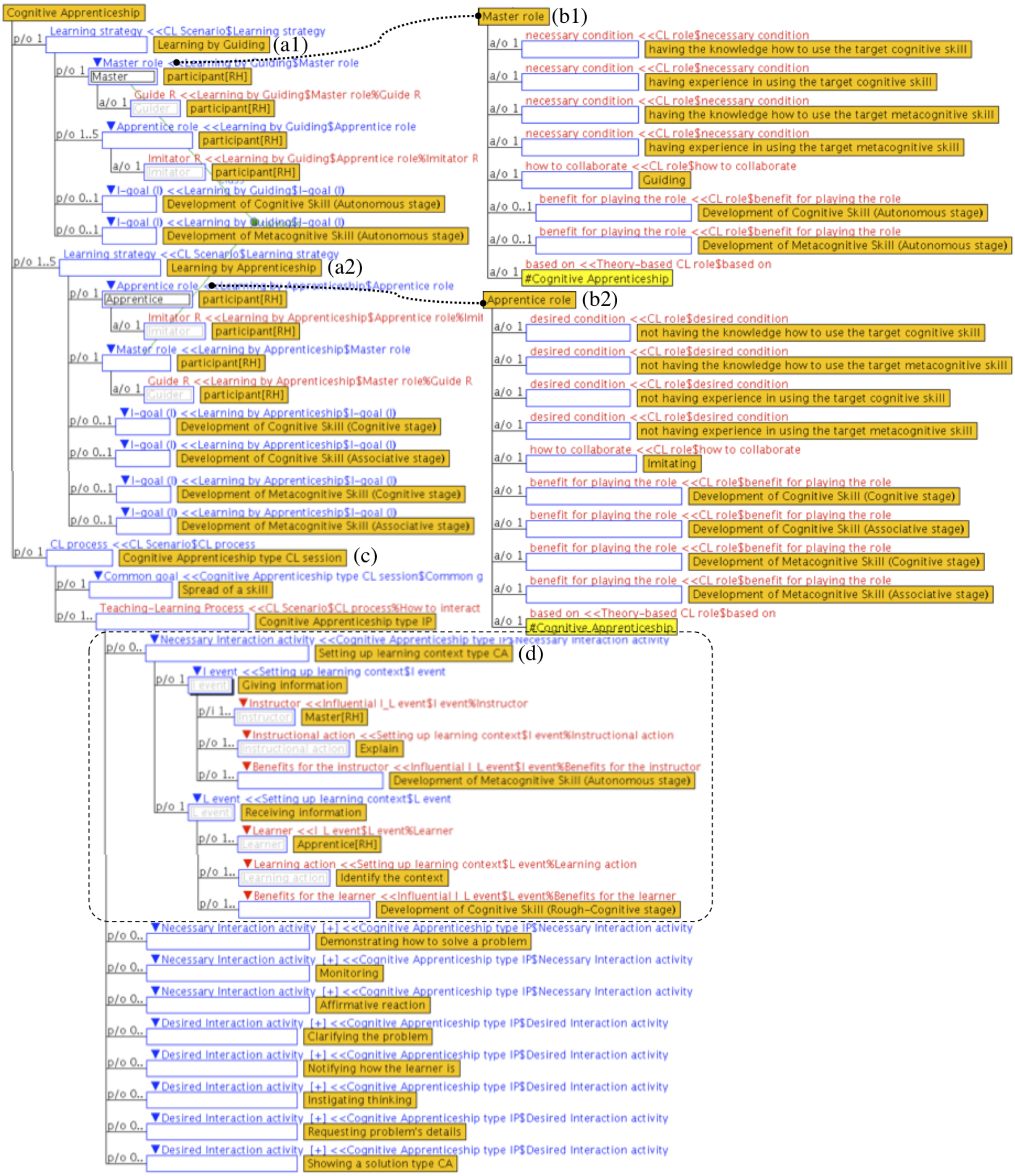
(d) The **Influential I_L event** represents the interaction among the group members and the benefits obtained by the interaction from two viewpoints: from the viewpoint of participants who play a role of instructor, and from the viewpoint of participants who play a role of learner. The influential I_L 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* through 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* through learning actions, and the expected *benefits for the learner* (*I-goal*).

As it was said before, the ontological structures shown in Figure 4 are used to delineate CL scenarios that compliant with instructional and learning theories. To illustrate this, Figure 5 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 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 is 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 5 (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

Figure 5 – Ontological structures to represent a CL scenario based on the cognitive apprenticeship theory

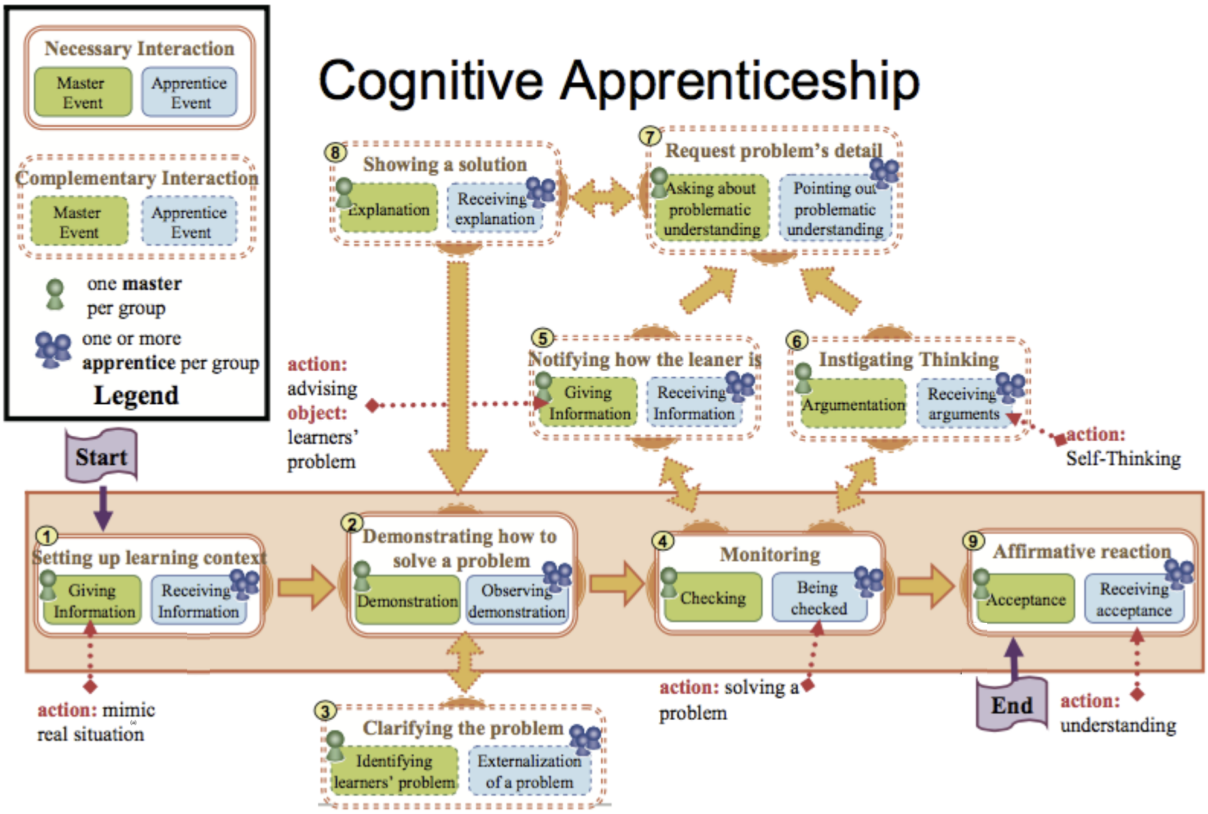


Source: Elaborated by the author.

or experience in how to use the target skill should play the apprentice role. Therefore, there are not necessary conditions in the ontological structure shown in Figure 5 (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 plays 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 5 (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 showed in Figure 6.

Figure 6 – Necessary and complementary interactions defined by the sequencing mechanism of a CSCL script inspired by the cognitive apprenticeship theory



Source: Adapted from Isotani (2009).

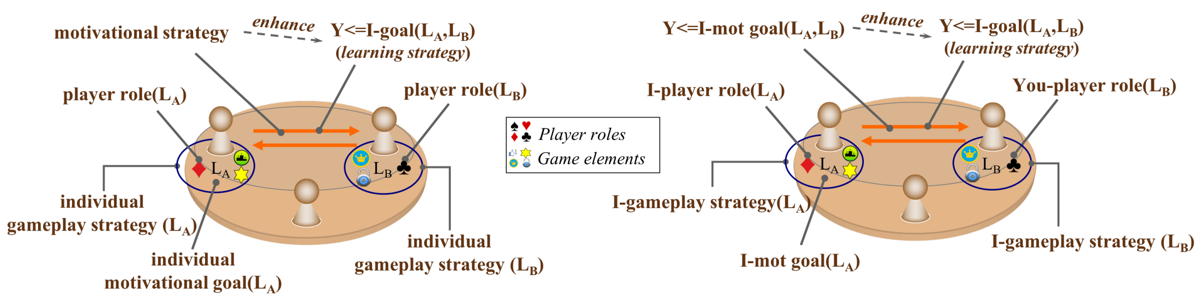
The necessary and desired interactions defined by the sequencing mechanism shown in Figure 6 are formalized as *Influential I_L event* in the *Teaching-Learning Process* of *Cognitive*

Apprenticeship type CL session showed in Figure 5 (c). The ontological structure to represent the interaction "*Setting up learning context type CA*" is shown in detail in Figure 5 (d). In this interaction, the instructional event "*Giving Information*" delineates 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*" delineates 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 7 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 7 – 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 indicates the implementation of the individual motivational strategy (*Y<=I-mot goal*) when this strategy corresponds to the gamification.

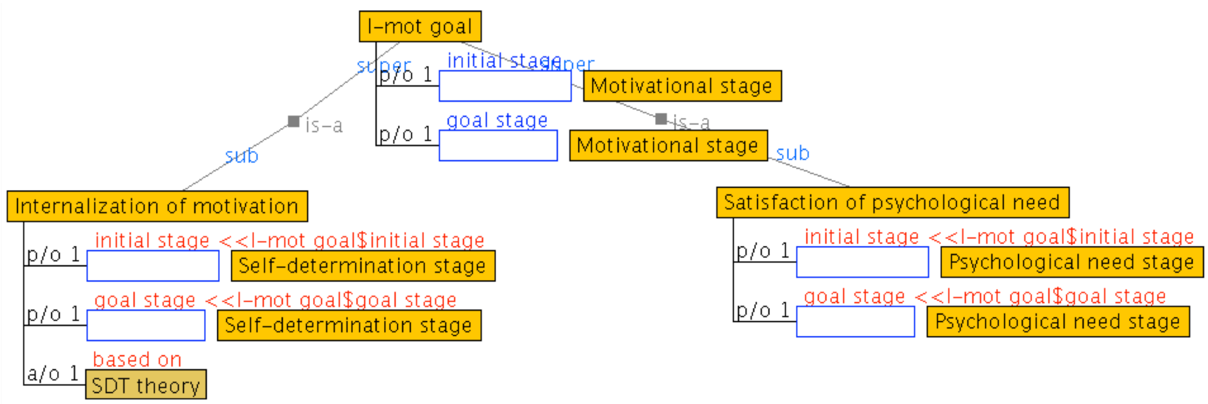
In the following subsections, the formalization of concepts, terms and relations briefly introduced here are detailed.

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. Thus, the individual motivational goal indicates the motivational stages that must be reached by a person to be motivated to interact with other.

Figure 8 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 8 – 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)



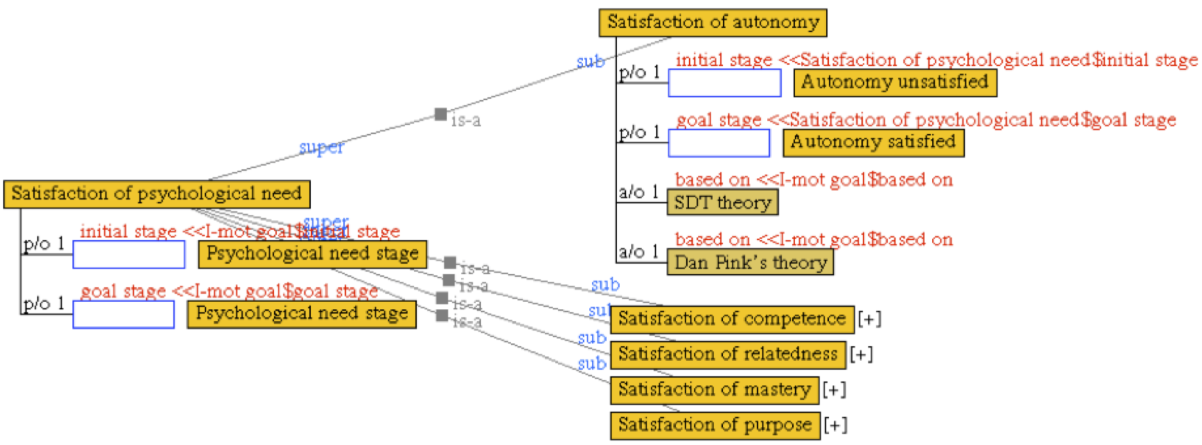
Source: Elaborated by the author.

Two types of individual motivational goals have been currently formalized in the ontology OntoGaCLeS to represent the individual motivational *goals (I*-mot goal) of 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 8 shows the representation for these two types of individual motivational goals. The initial and goal stages for 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.*, 2014b), the thesis author used the concept of "*Phychological need*" to refer the concept of "*Psychological need stage*," and he used the concept of "*Without need*" to refer the stages indicated as "*$1 need satisfied*" where $1 is substituted 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). So, motivation is a constructor that delineates 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, a motivation problem in a scripted collaborative learning 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*) have 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 satisfy only part of these needs that are referred by the thesis author 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).

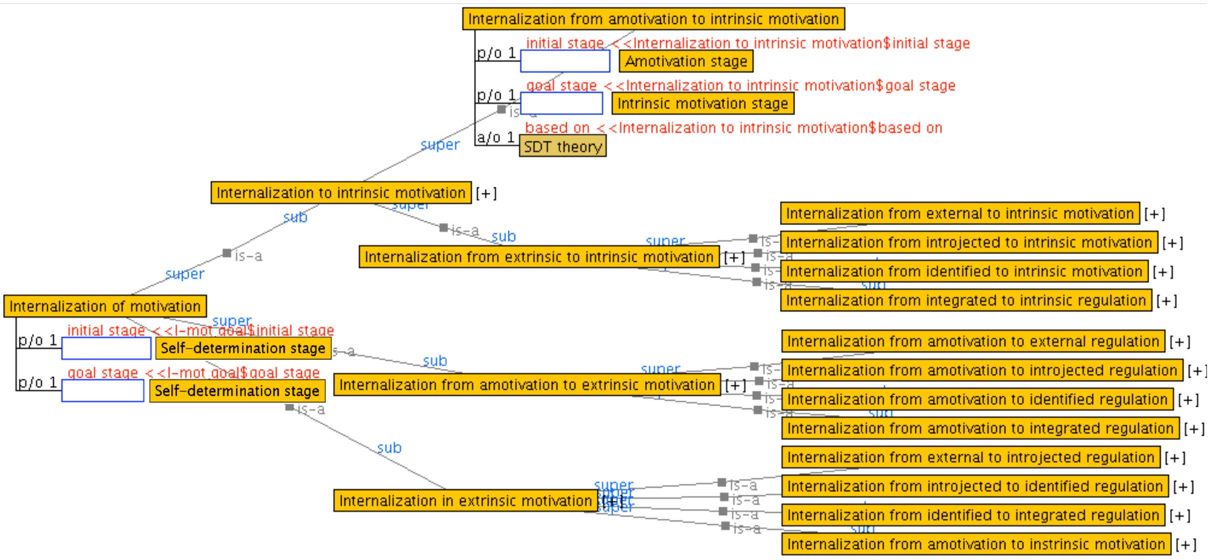
Figure 9 – Ontological structures to represent "*Satisfaction of psychological need*." At the top right, the ontological structure to represent "*Satisfaction of autonomy*."



Source: Elaborated by the author.

Figure 9 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 most 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). According to the Dan Pink's theory (PINK, 2011), a person is motivated and engagement in a cognitive, decision-making, creative or higher-order thinking task when he/she is given with autonomy, mastery and purpose. At the top right of Figure 9, the ontological structure to represent the *Satisfaction of autonomy* is detailed in which, based on an unipolar scale from an unsatisfied need stage to a satisfied need stage, the roles for the initial and goal stages are played by the *Autonomy unsatisfied* and the *Autonomy satisfied*, respectively. Employing the same unipolar scale, and the need-theories of motivation, SDT theory (DECI; RYAN, 2010) and Dan Pink motivation theory (PINK, 2011), a set of individual motivational goals as satisfactions of psychological needs have been formalized in the ontology OntoGaCLeS, and they are detailed in section A.2.

Figure 10 – 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). Thus, the internalization of motivation for the satisfaction of needs refers to changes in the motivation from a non-free choice to a free choice of needs 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 10 have been formalized to represent the *Internalization of motivation*. These ontological structures employ 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 *identify motivation* (fully internalized behave) to *intrinsic motivation* (automatically internalized behave). At the top right of Figure 10 is detailed the formalization for the change from *Amotivation stage* (*initial stage*) to *Intrinsic motivation stage* (*goal stage*) defined as "*Internalization from amotivation to intrinsic motivation*." The detailing of all ontological structures to represent the internalization of motivation is presented in section A.2.

3.2.2 Player Role

The identification of homogeneous people group that differs 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 psychological 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* formalized in the ontology OntoGaCLeS to define typologies of player types in the context of CL scenarios. Player roles delineate the functionality, responsibilities and requirements whereby participants of a group become 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 11. This structure defines the conditions that a participant must satisfy in the CL scenario to play the player role as *necessary condition* and *desire 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 represented by: *motivation state*, *psychological need state*, and *individual personality trait state*. A tree overview for these states is detailed in section A.1, where:

- The *motivation state* is an internal state that indicates the temporal attitudinal state of a person about 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 the participant's motivation, the motivation state represents a specific point in the whole process of being motivated, whereas the motivation stage represents an interval in a participant's motivation process.

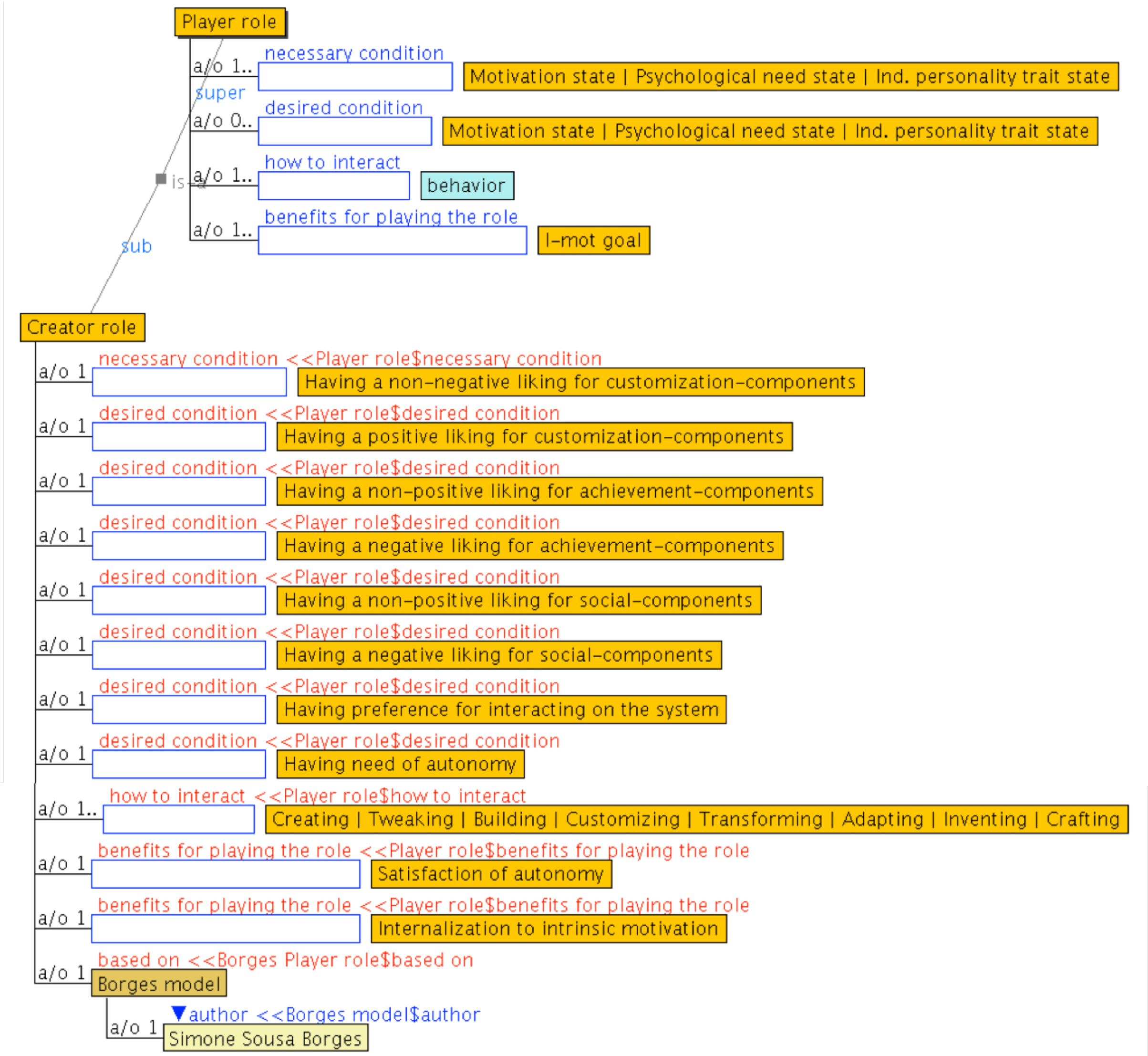
- The *psychological need state* represents the current psychological need of a person in which the states for each one of the psychological needs are formalized through the representation of pair states: "*Having need of $1*" and "*Not having need of $1*" in which "*$1*" is replaced by the name of the need that is being defined as prerequisite. For instance, to represent the states about 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* indicates states of the individual personality traits, such as introversion, extroversion, openness to experience, and conscientiousness. The individual personality trait states delineate the characteristics 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, the formalized individual personality traits states are: 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 the necessary and desired conditions that an individual should satisfy, the ontological structure to represent *Player role* shown in Figure 11 indicate 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 delineated as *behavior*s represent the possible manners in which a participant should interact to other, and concepts delineated as individual motivati*onal goals* (I-mot goal) represent the expected *benefits for playing the role*.

At the bottom of Figure 11, 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 instead of the liking for other game components are classified as creators. This segmentation is represented by the necessary condition of "*having a non-negative liking for customization-components*," and the desired conditions of "*having a positive liking for customization-components*," "*having a non-positive liking for achievement-component*," "*having a negative liking for achievement-*

Figure 11 – 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.

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

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

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

In the context of CL scenarios, an *individual motivational strategy* is the guidelines to motivate a participant to interact with other group members using a learning strategy. These guidelines are independent of any technology, so that the individual motivational strategy basically indicates what motivate 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 become an 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.

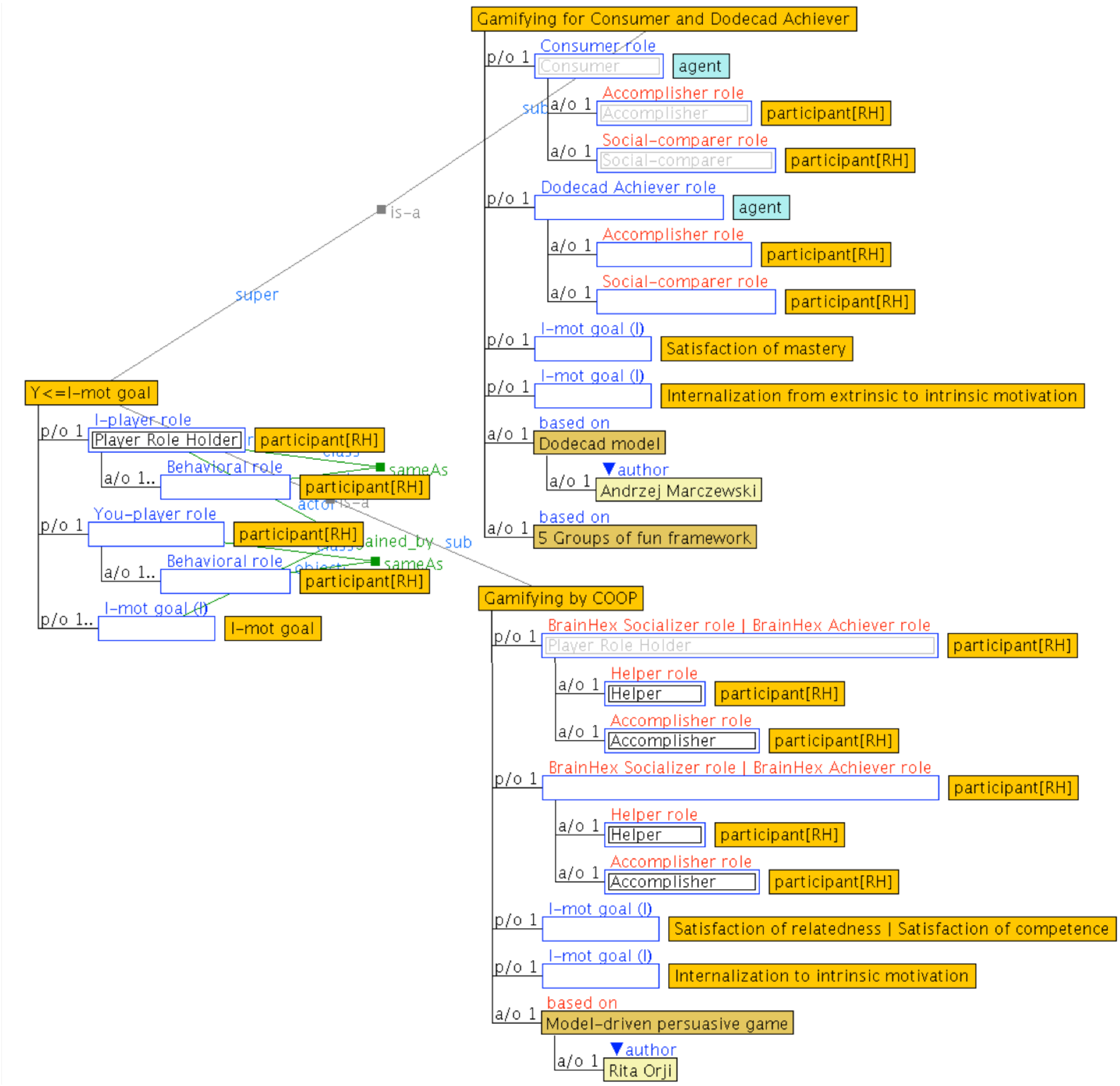
The ontological structure showed in Figure 12 represent the formalization of individual motivational strategies whose guidelines are extracted from gamification models or game design models. According to this structure, an *individual motivational strategy* (*Y<=I-mot goal*) is composed by:

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 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 12 – 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 12 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 showed at the top-right of Figure 12 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*."

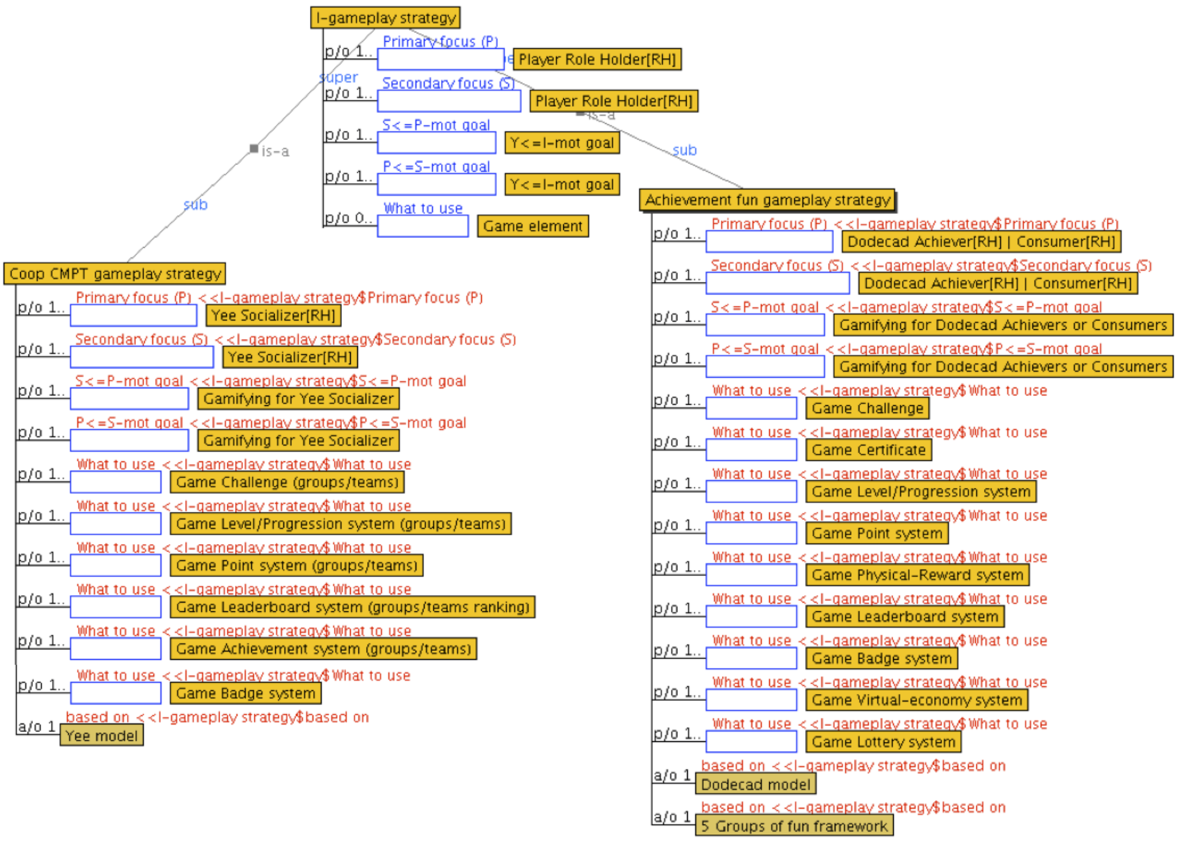
At the bottom-right of Figure 12, it is shown the ontological structure formalized to represent the application of the guidelines extracted from the Model-driven persuasive game for the cooperation strategy (ORJI; VASSILEVA; MANDRYK, 2014). These guidelines indicate cooperation as significant motivator 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 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 indicates the consequence of the application of the motivational strategy, it is expected changes in the motivational state for the participant in focus (*I*) from the amotivation or extrinsic motivated state to the intrinsic motivated state (*Internalization to intrinsic motivation*).

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

3.2.4 Individual Gameplay Strategy (I-gameplay strategy)

The guidelines extracted from the literature of gamification, game design and serious games are implemented through the design of way in which the users will experience their interactions with the game-like system (FABRICATORE; LÓPEZ, 2014; NACKE; DRACHEN; 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 under the concept of *individual gameplay strategy* (*I-gameplay strategy*). Thus, the gameplay of a gamified CL scenario is 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 the 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 13.

Figure 13 – 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 unnecessary for 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).

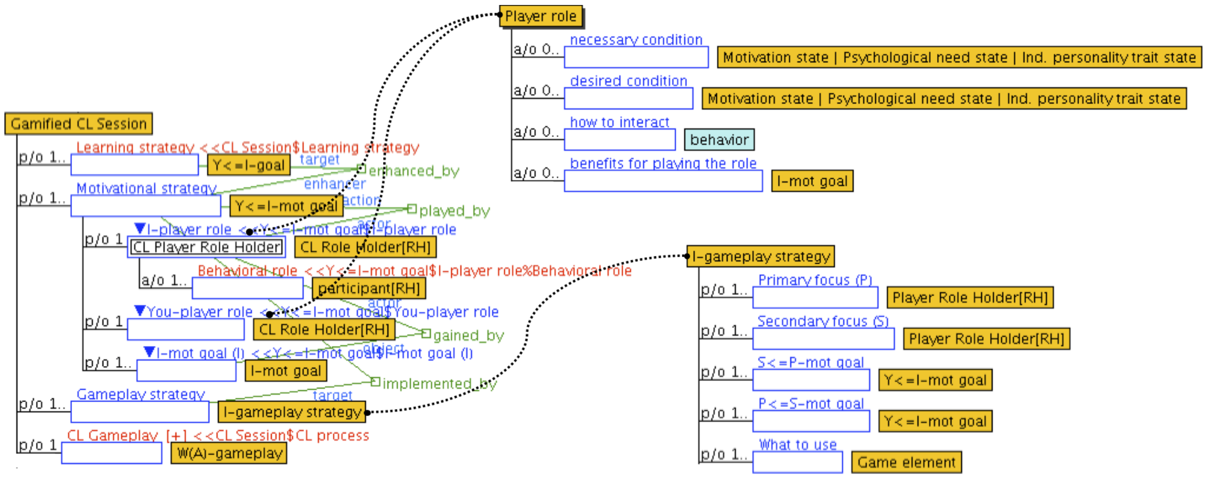
What to use indicates the game elements needed to act according to the individual gameplay strategy. Thus, the game elements defined in this attribute are the ones that are used to process the interactions of participants who are in the primary focus (P).

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 thesis author has inferred some individual gameplay strategies employing the guidelines of gamification and game design models. Figure 13 shows two examples of this formalization in which the guidelines from the Yee's model (YEE, 2006) have been used to develop 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. t

3.2.5 Gamified CL Scenario

A gamified CL scenario is a CL scenario in which the concepts earlier presented in this section have been properly applied to gamify it. In this sense, to represent a gamified CL scenario in the ontology OntoGaCLeS, the ontological structures proposed in the CL ontology to represent a CL scenario (Figure 4) 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 14.

Figure 14 – 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*) indicates the guidelines used to enhance the learning strategy employed by the participant in focus (*I*), and the individual gameplay strategy (*I-gameplay strategy*) indicates 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 14), 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*).

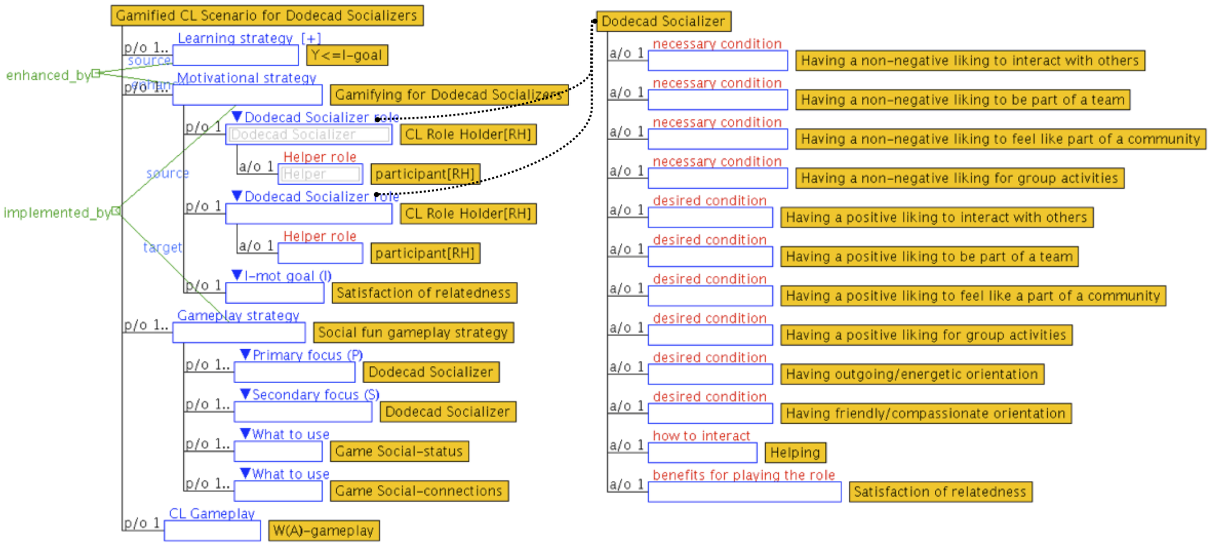
To illustrate the use of the ontological structures proposed in Figure 14, a gamified CL scenario for participant who plays the Dodecad Socializers has been formalized as shown in Figure 15, where the learning strategies (*Y<=I-goal*) of participants are *enhanced by* the individual motivational strategy "*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*). Thus, 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 support the social fun gameplay strategy. This inference pertains to the thesis author, 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 15 – 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 ontological structures presented in the previous section, the thesis author 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 build 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 14. 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) has been used as source of information.

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 why player roles cannot be assigned to a participant when he/she plays the CL role. Chart 2 shows the result of this step (1) for the CL roles of "*Peer-Tutor*" and "*Peer-Tutee*" defined in CL Scenarios based on the Peer-tutoring theory. Counterproductive behaviors of player roles are avoided to not interfere with the expected behaviors of CL roles. Thus, for example, participants who are playing the CL roles of Peer-tutor and Peer-tutee cannot play the *Griefer roles* because they want to negatively affect other users.

Chart 2 – Dodecad player roles that can be assigned for participants of a Peer-tutoring scenario

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

Source: Elaborated by the author.

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.

Chart 3 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 commonly expected behaviors indicated in the guidelines of player roles "*I-Player role*" and "*You-Player role*."

Chart 3 – 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		
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

Source: Elaborated by the author.

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 Chart 3, 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 an 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 support the behaviors indicated in the guidelines of individual motivational strategies to accomplish the expected benefits indicated as individual motivational goals. Chart 4 shows the results of this step for the ontological model to personalize the gamification in Peer-tutoring scenarios.

Chart 4 – 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

Source: Elaborated by the author.

The individual gameplay strategies indicated in the Chart 4 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.

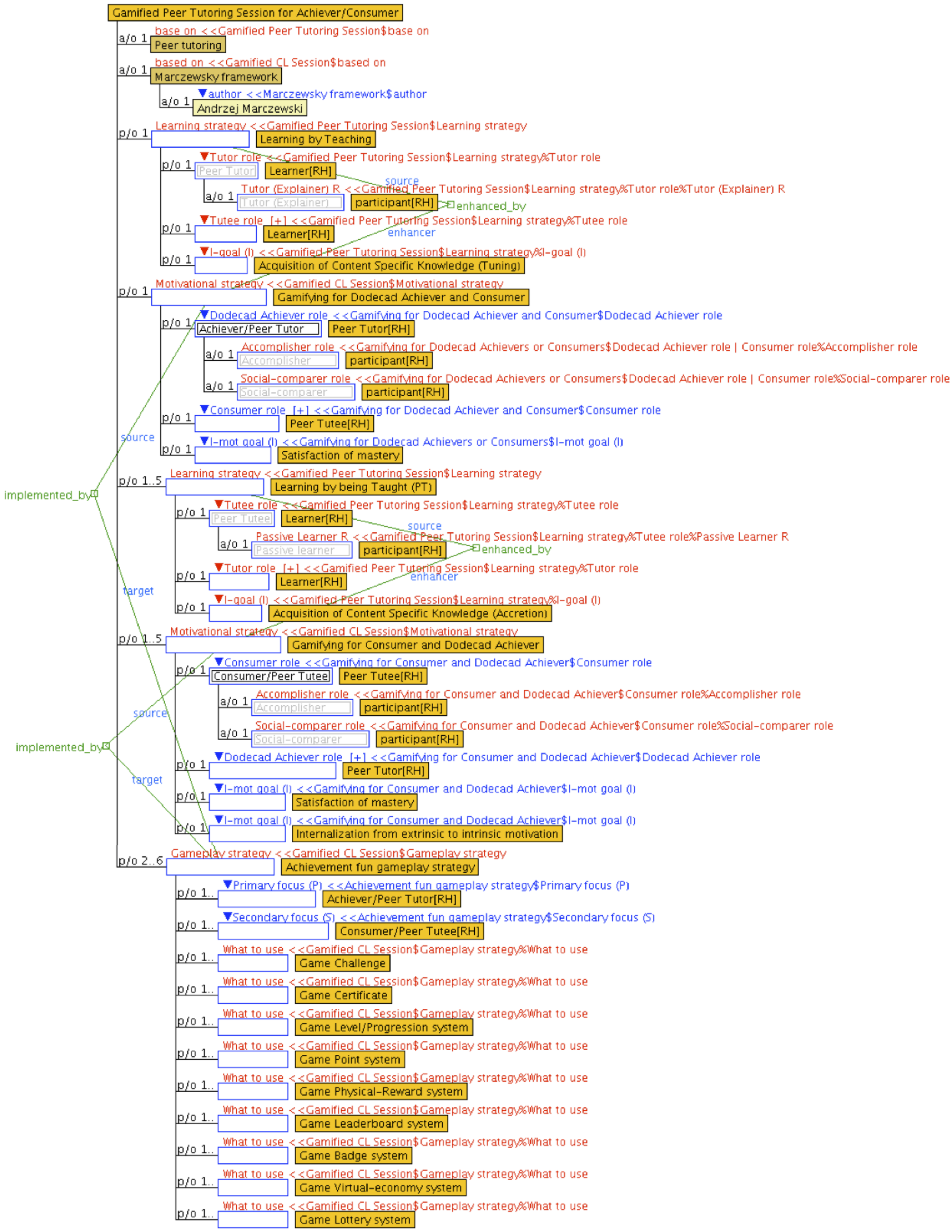
- *Social fun gameplay strategy*: is an individual motivational strategy in which social status is used to support the feeling of relatedness. In this sense, the system should provide some form of social network/group to indicate and/or create group/collective game elements. Thus, the system would use a point 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 satisfies the need of purpose. This satisfaction comes from collection of trading valuable things. So when participants help to others, game elements are collected to be converted into something that has an important 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 Chart 4, 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 16 – Ontological structure to represent "*Gamified Peer Tutoring Scenario for Achiever/Consumer*"



Source: Elaborated by the author.

Figure 16 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 type models and need-based theories of motivation have been formalized in the ontology OntoGaCLeS to solve the context-dependency related to the individual characteristics of participants when a CL scenario is been gamified to deal with motivation problems in a scripted collaborative learning. The formalization of these concepts consists in ontological structures to represent individual motivational goals, player roles, motivational strategies, individual gameplay strategies, and gamified CL scenarios.

Through 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 from the Dodecad player type model is employed to develop 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, computational mechanisms and procedures 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 provides theoretical justification in an algorithm that help the users to gamify CL scenarios. **??** shows a computational mechanism developed by the thesis author as proof of concept to set player roles for students in the Moodle platform.

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APPENDIX

A

ONTOLOGY ONTOGACLES: CONCEPTS, TERMS AND ONTOLOGICAL STRUCTURES

A.1 Tree Overview of States

A.1.1 Motivation States

- Any
  - Common world
    - Universal
    - equivalence
    - Particular
      - substrate
      - entity
        - physical
          - occurrent
            - stative
              - stative_2
                - state
                  - object state
                    - internal state
                      - hunger state
                      - life state
                      - Internal agent state
                        - Attitudinal state
                          - Affective state
                          - Temporal attitudinal state
                            - Future condition state
                            - Current condition state
                              - Aspiration
                              - Relevance
                              - Motivation state
                                - Motivated
                                  - Intrinsic motivated
                                  - Extrinsic motivated
                                - Not motivated
                              - Confidence

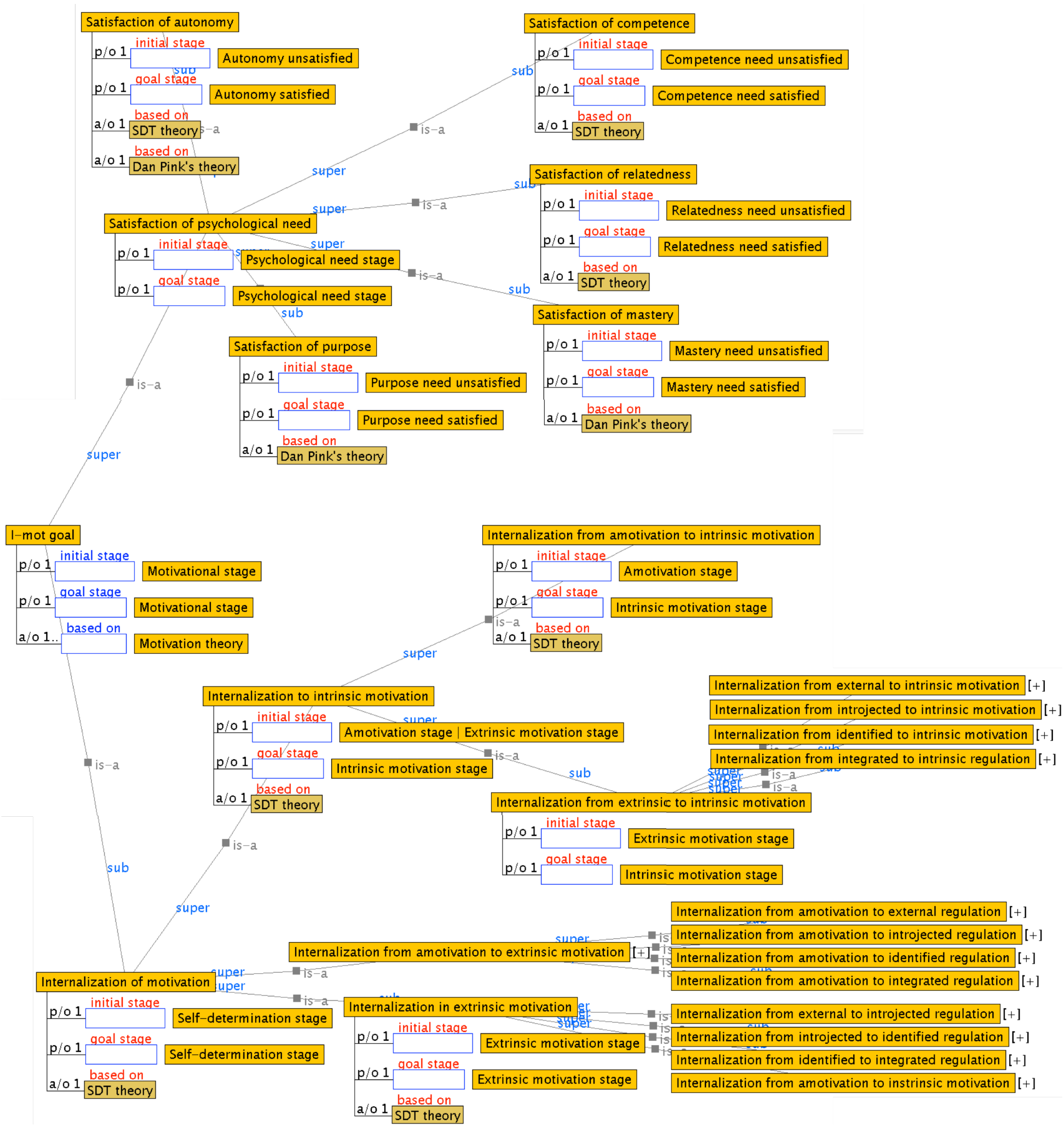
A.1.2 Psychological Need States

- state
  - object state
    - internal state
      - hunger state
      - life state
      - Internal agent state
        - Attitudinal state
        - Progression state
        - Developmental state
        - Cognitive process state0
        - Human need state
          - Existence need state
          - Psychological need state
            - Relatedness need state
              - Love/belonging need state
                - Power need state
                  - Having need to demonstrate power
                  - Not having need to demonstrate power
                - Display status need state
                - Feel admiration need state
              - Social-esteem need state
                - Social status need state
                  - Having need to demonstrate his/her social status
                  - Not having need to demonstrate his/her social status
              - Having need of relatedness
              - Not having need of relatedness
            - Growth need state
              - Self-actualization need state
                - Individuality need state
                - Creativity need state
                - Autonomy need state
                  - Having need of autonomy
                  - Not having need of autonomy
                - Purpose need state
                  - Having need of purpose
                  - Not having need of purpose
              - Self-esteem need state
                - Mastery need state
                  - Having need of mastery
                  - Not having need of mastery
                - Competence need state
                  - Having need of competence
                  - Not having need of competence
                - Self-confidence need state
                  - Having need of self-confidence
                  - Not having need of self-confidence
        - Ind. personality trait state
      - Internal non-agent state

A.1.3 Individual Personality Trait States

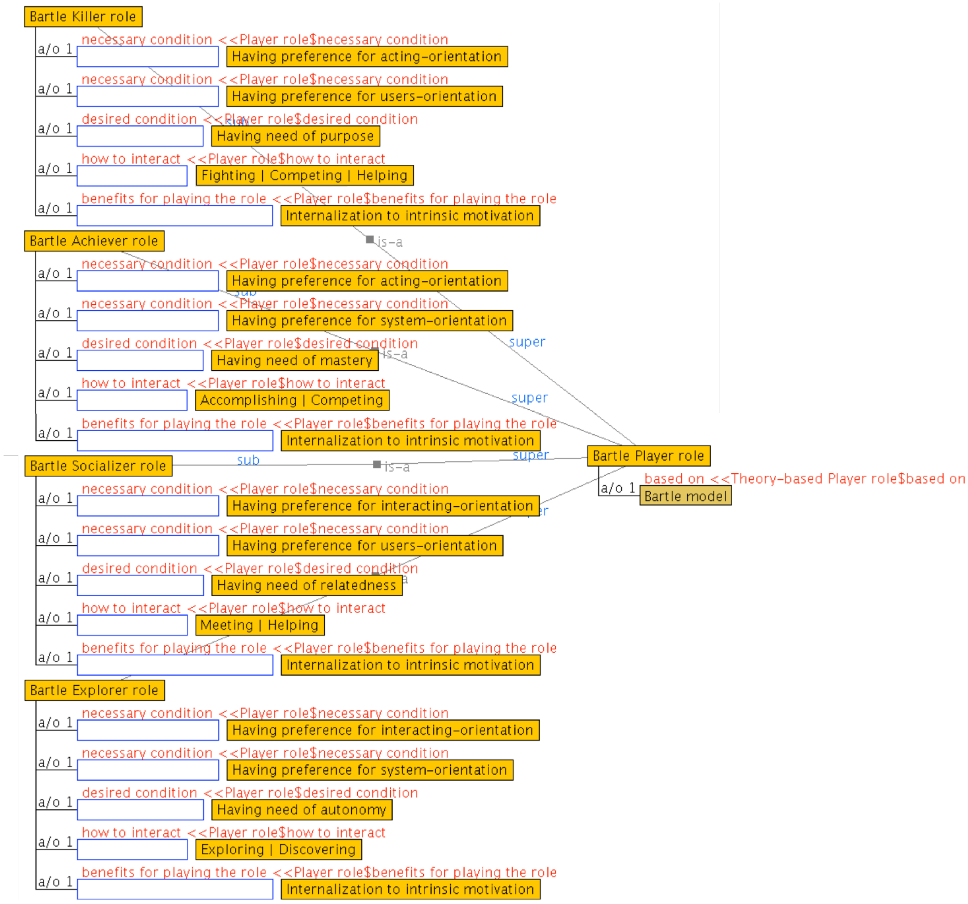
- Ind. personality trait state
  - Game style preference state
    - Having preference for acting on the system
    - Having preference for interacting on the system
    - Having preference for acting with others users
    - Having preference for interacting with others users
    - Users/System state
    - Interacting/Acting state
  - MBTI personality traits state
    - Introversion/Extraversion
      - Having introversion orientation
      - Having extraversion orientation
    - Intuition/Sensing
      - Having intuition orientation
      - Having sensing orientation
    - Feeling/Thinking
      - Having feeling orientation
      - Having thinking orientation
    - Perception/Judging
      - Having perception orientation
      - Having judging orientation
  - Game liking preference state
    - Liking to help others to orient themselves in new situations
    - Liking to share my knowledge
    - Liking to put effort according to the reward
    - Liking achievement-components
    - Liking social-components
    - Liking immersion-components
    - Liking discovery-components
    - Liking customization-components
    - Liking competition-components
    - Liking advancement-components
    - Liking mechanics-components
      - Having a non-positive liking for mechanics-components
        - Having a negative liking for mechanics-components
        - Having indifference liking for mechanics-components
      - Having indifference liking for mechanics-components
      - Having a non-negative liking for mechanics-components
        - Having a positive liking for mechanics-components
        - Having indifference liking for mechanics-components
  - Big five personality traits state
    - Openness state
    - Conscientiousness state
    - Extraversion state
    - Agreeableness state
    - Neuroticism state
      - Having sensitive/nervous orientation
      - Having secure/confident orientation

A.2 Individual Motivational Goal (I-mot goal)

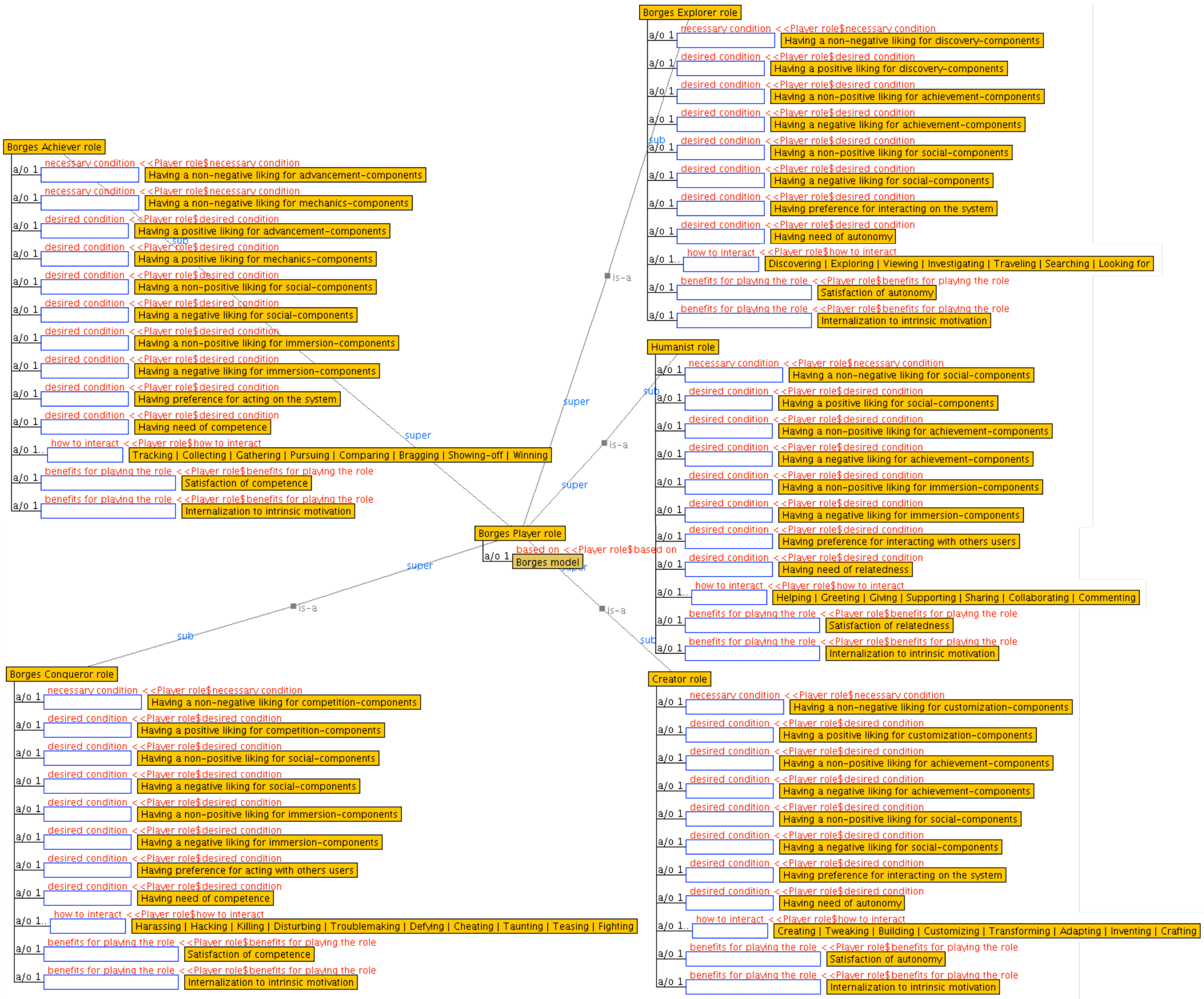


A.3 Player Role

A.3.1 Player Roles based on the Bartle Model



A.3.2 Player Roles Based on the Borges Model

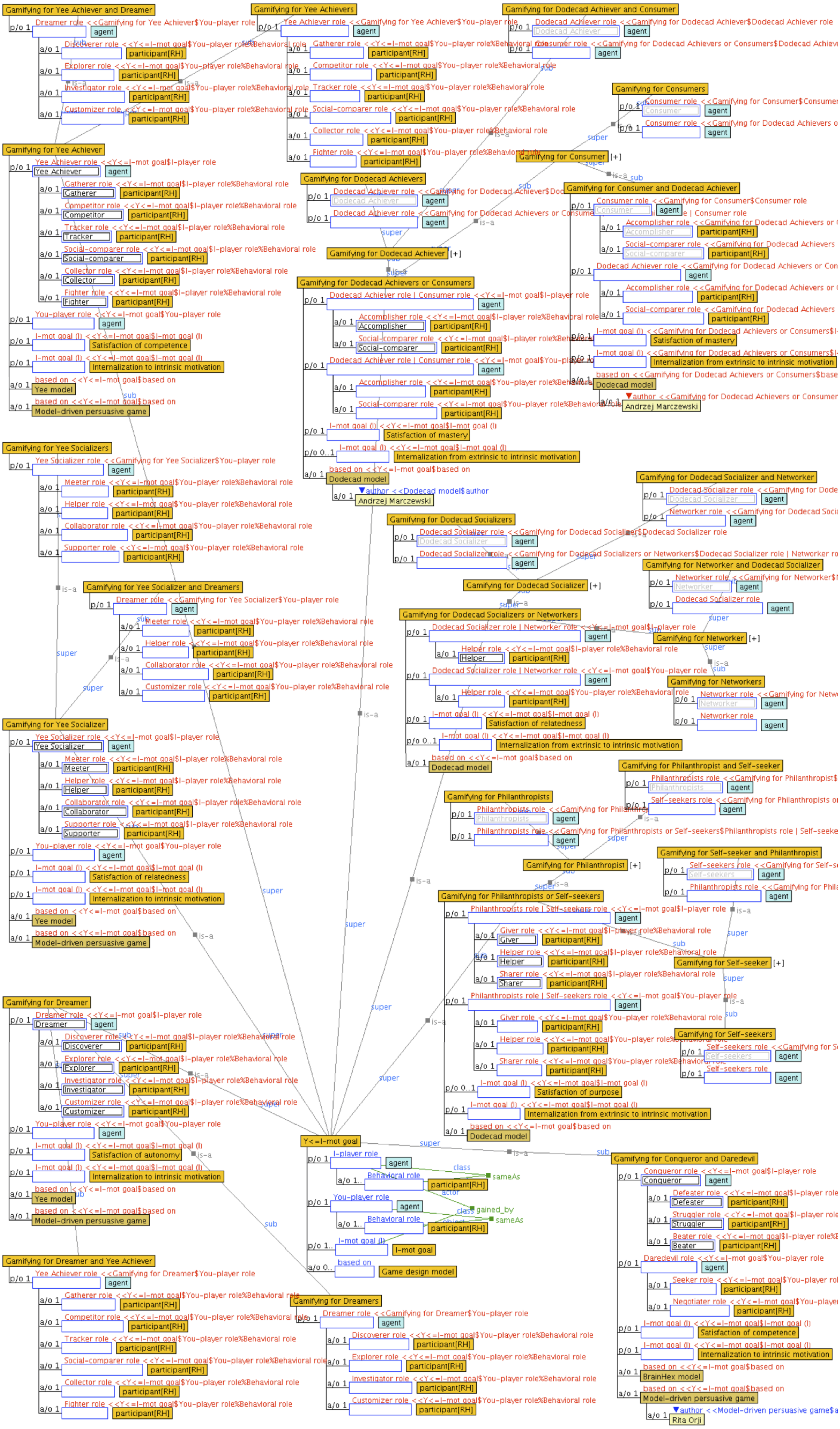


A.3.3 Player Roles Based on the Yee Model

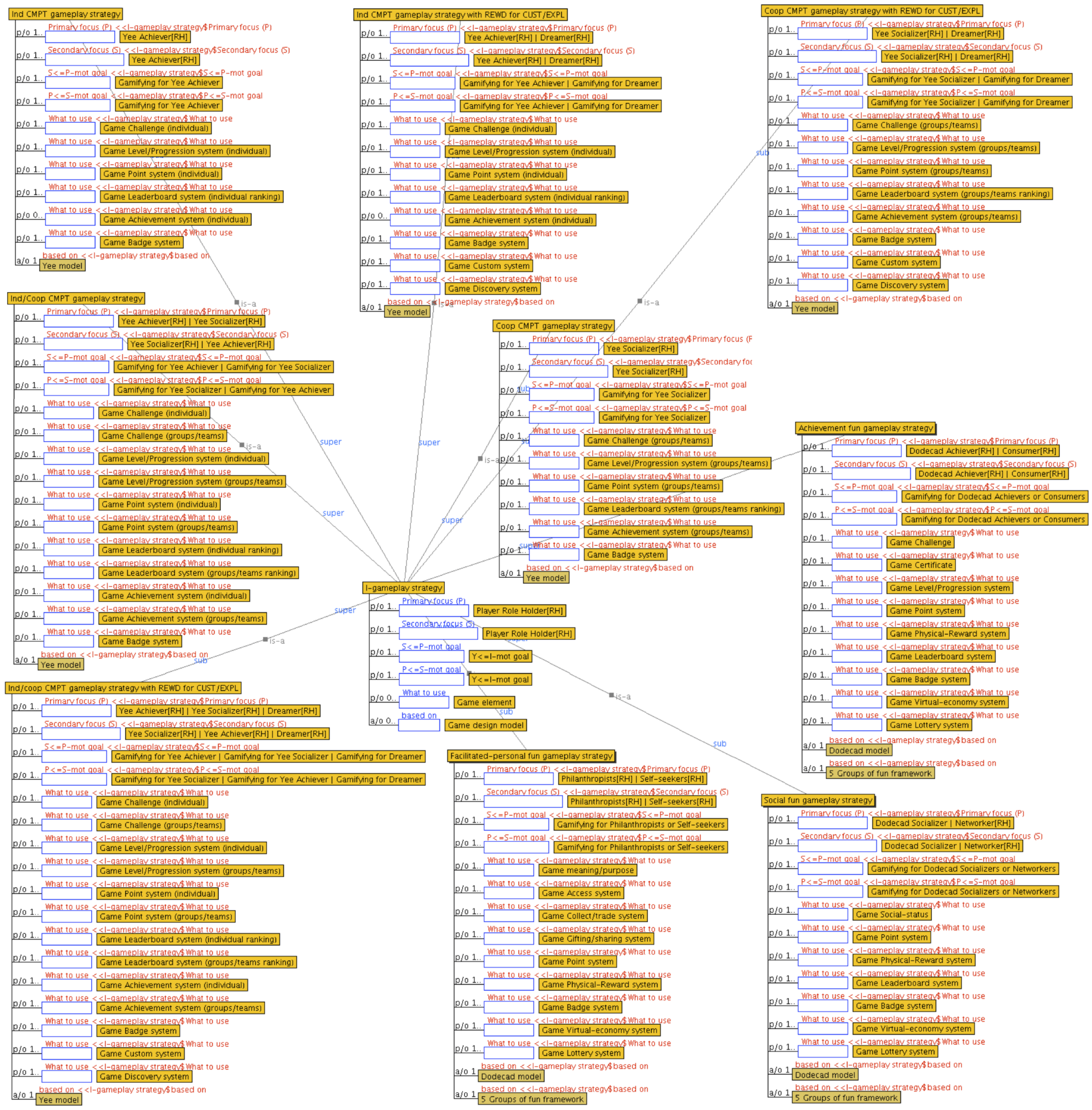
A.3.4 Player Roles Based on the Dodecad Model

A.3.5 Player Roles Based on the BrainHex Model

A.4 Individual Motivational Strategy (Y<=I-mot goal)



A.5 Individual Gameplay Strategy (I-gameplay strategy)



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