Gamification of Collaborative Learning Scenarios: An Ontological Engineering Approach to Deal with Motivational Problems in Scripted Collaborative Learning

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Abstract. *To date, one of the major problems in the field of Computer-Supported Collaborative Learning (CSCL) is to engage students in meaningful interactions. Past research has addressed this issue by using scripts, a procedure that humans and computers can use to reduce extraneous interactions. Nevertheless, it has caused negative learning outcomes and motivational problems over time. Thus, in our work, we propose an innovative approach that combines gamification, a strategy to increase engagement, and personalization to improve the chances of successful learning. Both gamification and personalization of collaborative learning (CL) are complex tasks that require a specific organization of knowledge about game-design and theories of human learning. To deal with this, we formalize such knowledge into an ontology and, on top of it, we built computational tools, procedures, and mechanisms to support well-thought-out gamified CL activities. We conducted three full-scale empirical studies during a semester in real situations with around 60 students each. Findings of these studies have shown statistically significant differences between our approach and the current state of the art. We found positive effects of our approach on students' intrinsic motivation and skill/knowledge acquisition with a strong positive correlation among them. To the best of our knowledge, this is the first work that developed an effective and efficient method to deal with motivational problems.*

1. Introduction

In CSCL, scripts orchestrate and structure the CL promoting meaningful, fruitful and significant interactions among students [Fischer et al. 2013]. Despite these benefits, motivational problems may occur in scripted CL. The lack of motivation, also known as amotivation, may be caused by the sense of obligation to following an unwilling sequence of interactions, the lack of interest in content-domain, and the learners' preference to work individually. The demotivation problem, as the loss of initial motivation, may be caused by a coercion degree of scripts when there is a lack of choice over their sequence of interactions [Dillenbourg 2002], difficulty to perform structured tasks [Isotani 2009], and when they are executed for a long time [Schmitt and Weinberger 2018]. Motivational problems degrade the level of participation [Wu et al. 2014], persistence, and effort [Weinberger et al. 2005], which may cause negative learning outcomes, such as superficial interactions, and a low level of knowledge elaboration [Xie and Ke 2009].

To deal with motivational problems, Gamification has been pointed out by many researchers and practitioners as a promising approach to engage students in educational contexts [Koivisto and Hamari 2018]. However, gamification is too context-dependent

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[Richards et al. 2014]. Thus, the gamification is a non-trivial task, and when the game elements are not properly applied by tailoring them for each situation, gamification may cause negative effects [Toda et al. 2018], such as detrimental on students' interest, cheating, embarrassment, and a lack of credibility.

A personalization of gamification for CL scenarios needs to rely on knowledge from game design, and from theories and practices of motivation and human behavior because motivation varies from individual to individual, from situation to situation, and it varies in amounts and types [Deci and Ryan 2010]. Such knowledge hereinafter referred to as *theories and practices of gamification*, currently lack formal vocabulary and common definitions. This fact hinders the creation of models/frameworks that can be applied by computational systems to help instructional designers in the gamification of CL sessions based on these theories. In this sense, developing a systematic way to represent in an unambiguous way the knowledge from theories and practices of gamification is necessary to obtain these computational systems. Furthermore, this knowledge must be properly aligned with knowledge from instructional design and theories of human learning to ensure the accomplishment of pedagogical goals through CL scenarios.

Ontologies have been consolidated as the most advanced technology to support the explicit representation of knowledge in a common understandable and shareable manner for computers and humans [Mizoguchi and Bourdeau 2016]. Through this representation, ontologies can be used to delineate concepts from *theories and practices of gamification* without ambiguities, and by taking advantages of the Internet interconnection, ontologies with these concepts can be used as a language to share their understandings and interpretations. Thereby, our main research objective was *to develop a solution that integrates gamification and ontologies to deal with motivational problems in scripted CL*. The next sections are structured as follows: firstly, Sec. 2 presents the related works. Sec. 3 presents our proposed solution to deal with motivational problems in scripted CL. Sec. 4 describes the research methodology. Sec. 5 presents the findings obtained in empirical studies to validate our approach. Sec. 6 shows the conclusions and contributions of our work.

2. Related Works

Dealing with motivational problems in scripted CL is a challenge addressed by the CSCL community for many years [Dillenbourg 2002]. One traditional approach is the use of instructional design models that focus on motivation. These models, such as the ARCS model [Keller 2009], the time continuum model [Wlodkowski and Ginsberg 2017], and the taxonomy of intrinsic motivations for learning [Malone and Lepper 1987], can be used as guidelines to define a better way in which learning environments, activities, content, and resources should be developed to motivate the students to follow an effective and efficient CL process. Another traditional approach to deal with motivational problems in scripted CL is the the regulation of affective states through motivational dialogs. These motivational dialogs are messages, such as "*Let's keep going*", and computational systems known as *Affective feedback systems* can be developed to engender these dialogs based on the identification of learners' affective states. Thus, for example, the intelligent system "*Guru*" [Olney et al. 2012] was developed to deal with the demotivation during collaborative lectures. [Tian et al. 2014] built a system that sends advice in peer-learning activities to regulate the participants' emotions when it identifies boredom, frustration or fury. Finally, as the last example, we have *emotcontrol* [Feidakis et al. 2014], a tool in which the participants indicate their current affective states, and based on these states, the tool engenders motivational dialogs in form of empathic dialogs during the CL process.

Instructional design models and affective feedback systems are considered traditional approaches because they are based on the assumption that the good quality of instructional materials and the content-domain by itself is compelling and interesting for everyone. This assumption ignores the fact that some learners may dislike the content-domain, environments, activities or resources used in the CL process. In this sense, efforts of the CSCL community has been directed to finding new innovative solutions that, besides to motivate and engage students during the entire CL process, are not completely tied to the domain-content and desired to learn to work in groups. In this direction, gamification has picked the attention of many several researchers. However, in the literature, only one approach was found in which, to personalize the gamification of CL scenarios, machine learning is used to identify individual profiles of gamification [Knutas et al. 2017]. However, this solution is not oriented to deal with motivational problems in the scripted CL, and its purpose is to increase the communication of the participants.

3. An Ontological Engineering Approach to Gamify CL Scenarios

Fig. 1 shows our ontological approach to gamify CL scenarios proposed as a solution to deal with motivational problems in scripted CL.

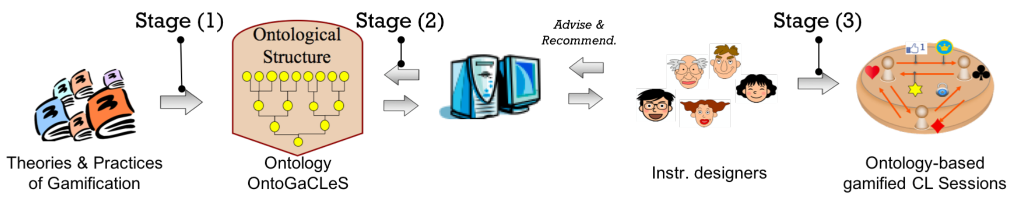

Fig. 1. Ontological engineering approach to gamify CL scenarios.

This approach consists of three major stages described as follows: The stage (1) is the application of ontology engineering in the theories and practices of gamification to represent the knowledge about how to gamify CL scenarios into an ontology OntoGaCLeS[1] - part of this ontology is shown in Fig. 2 in which there are: (A1) the ontological structure to represent the *Yee Socializer role* (player role), and (A2) the ontological structure to represent the *Gamified Cognitive Apprenticeship Sessions for Yee Achiever/Yee Socializer* (ont-gamified CL session). The stage (2) is the development of computational mechanisms and procedures based on our ontology to support the gamification of CL scenarios. In the stage (3), this computational support aims to be given through tools in form of advice and recommendations to obtain tailored gamified CL sessions known as ontology-based gamified CL sessions (called in short, *ont-gamified CL sessions*).

Fig. 2 shows the computational mechanisms and procedures developed on top of our ontology, and they are: a conceptual flow to gamify CL sessions shown in Fig. 2 (B), a pseudo-algorithm to set player roles illustrated in Fig. 2 (1), a procedure to design the CL gameplay illustrated in Fig. 2, and a reference architecture of intelligent theory-aware systems to gamify CL sessions shown in Fig. 2 (C). As part of the procedure to design the

[1] `https://github.com/geiser/ontogacles`

CL gameplay, to define the values of rewards for each interaction of the scripted CL, we also developed a GIMF model - illustrated in Fig. 2 (2b) - that integrates the balance of challenge/ability proposed by the flow theory with the Learner's Growth Model (LGM) proposed by [Isotani 2009]. We also proposed a theory-aware tool that, in a prescriptive way, uses the WAY-knowledge base to represent the design rationale to gamify a non-game event, such as the *Setting up learning context type CA* illustrated in Fig. 2 (2c).

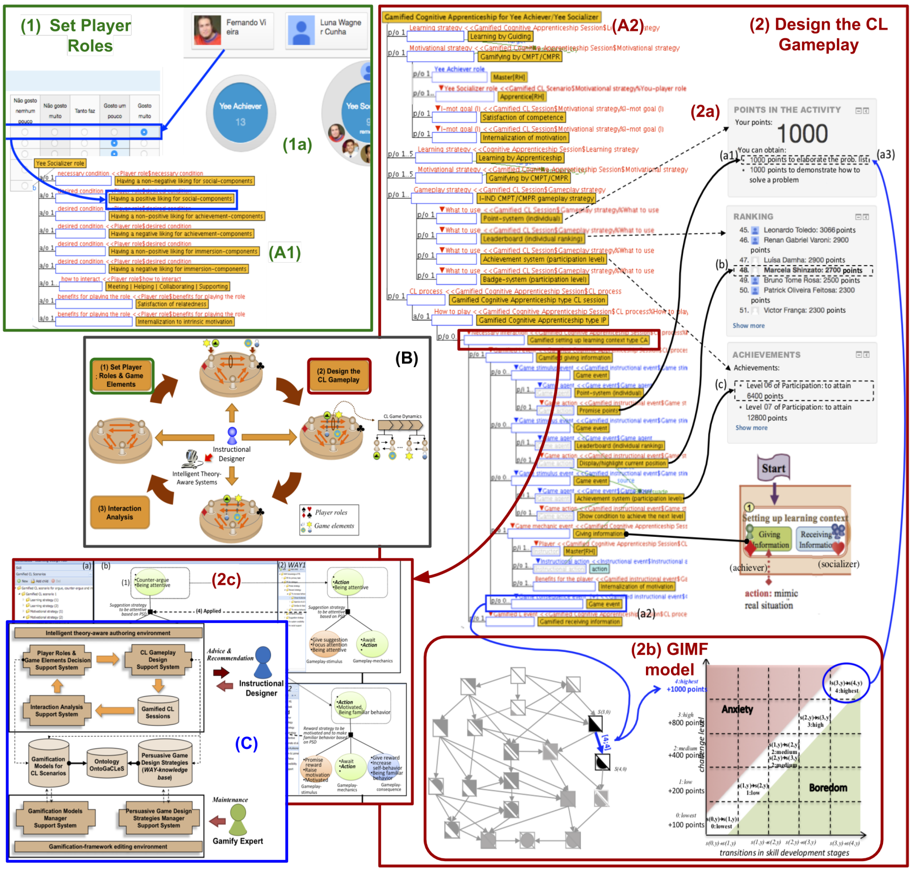

Fig. 2. Mechanisms/procedures developed on top of the ontology OntoGaCLeS.

4. Research Methodology

As our work aims to achieve theoretical and empirical contributions, the mixed research methodology proposed by [Glass et al. 2002] was carried out in four iterative phases: informational, propositional, analytical and evaluation. Through scientific (observing the world) and engineering (observing existing solutions) research methods, in the informational phase, we achieved the theoretical contributions referred as the identification of relevant concepts from theories and practices of gamification for dealing with motivational problems in scripted CL. During the propositional phase, through ontology engineering, we formalized ontological structures into the ontology OntoGaCLeS to represent the relevant concepts identified in the informational phase. On top of this ontology, during the analytical and evaluation phases, we achieved the empirical contributions referred to as the development of computational tools, methods, and procedures to support the well-though-out gamification of CL sessions. In this phase, we also validated our approach through empirical studies conducted in real situations in which we assessed the effectiveness and efficiency of our approach to deal with motivational problems in scripted CL.

5. Empirical Studies and Results

One-pilot and three full-scale empirical studies were carried out to: analyze "*the effects of ont-gamified CL sessions on the students' motivation and learning outcomes*" for "*validating our ontological engineering approach*" concerning "*the effectiveness and efficiency to deal with motivational problems in scripted CL.*" The effectiveness was evaluated in the pilot, 1st and 2nd studies by comparing ont-gamified CL sessions (experimental condition) against non-gamified CL sessions (control condition) using as metrics students' motivation and learning outcomes. Efficiency was evaluated in the 3rd study by comparing students' motivation and learning outcomes in ont-gamified CL sessions (experimental condition) against gamified CL sessions that use the current state of the art approach to gamify an activity (control condition, in short, called *w/o-gamified CL sessions*). These studies were carried out in real situations with undergraduates students in the course of *Introduction to Computer Science* offered at the University of São Paulo. Thereby, the CL sessions for the empirical studies have been instantiated using a CSCL script inspired by the Cognitive Apprentice theory, and to three CL activities with the subjects of: *conditional structures* for the 1st empirical study (with $N = 62$ students); *loop structures* for the pilot study (with $N = 39$) and 2nd empirical study (with $N = 58$); and *recursion* for the 3rd empirical study (with $N = 59$).

All the empirical studies were executed with a 2×2 factorial design, and employing pre-test, intervention, and post-test phases. During the pre-test, multiple-choice knowledge questionnaires and programming problem tasks were applied to the students to determine their CL roles (master or apprentice) in the CL sessions. In the intervention phase, this CL role assignment was performed through the theory-driven algorithm proposed in [Isotani 2009], and with a randomized assignment of students for the type of CL session (non-gamified CL session - as exemplified in Fig. 3 (a), w/o-gamified CL session - as exemplified in Fig. 3 (b), and ont-gamified CL sessions - as exemplified in Fig. 3 (c), (d) and (e). For the pilot, 1st and 2nd empirical studies, the ont-gamified CL sessions were instantiated from the structures "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever and Apprentice/Yee Achiever*" and "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Socializer and Apprentice/Yee Socializer*." Thus, as exemplified in Fig. 3 (c), for an apprentice student who plays the Yee Achiever role because he/she had more liking for achievement-components than for social-components, an individual competition was set up to him/her by using: individual achievements - shown in Fig. 3 (c1) - with badges based on levels of individual participation - shown in Fig. 3 (c2), individual point-systems - shown in Fig. 3 (c3), and a leaderboard of individual rankings - shown in Fig. 3 (c4). For an apprentice student who plays the Yee Socializer role because he/she had more liking for social-components than for achievement-components, as exemplified in Fig. 3 (d), a collaborative competition was established using: team achievements - shown in Fig. 3 (d1) - with badges based on levels of collaborative participation - shown in Fig. 3 (d2), point-systems for groups - shown in Fig. 3 (d3), and a leaderboard with rankings for teams - shown in Fig. 3 (d4).

For the 3rd empirical study, the ont-gamified CL sessions were instantiated from the structures "*Gamified Cognitive Apprenticeship Scenario for Master/Yee Achiever*

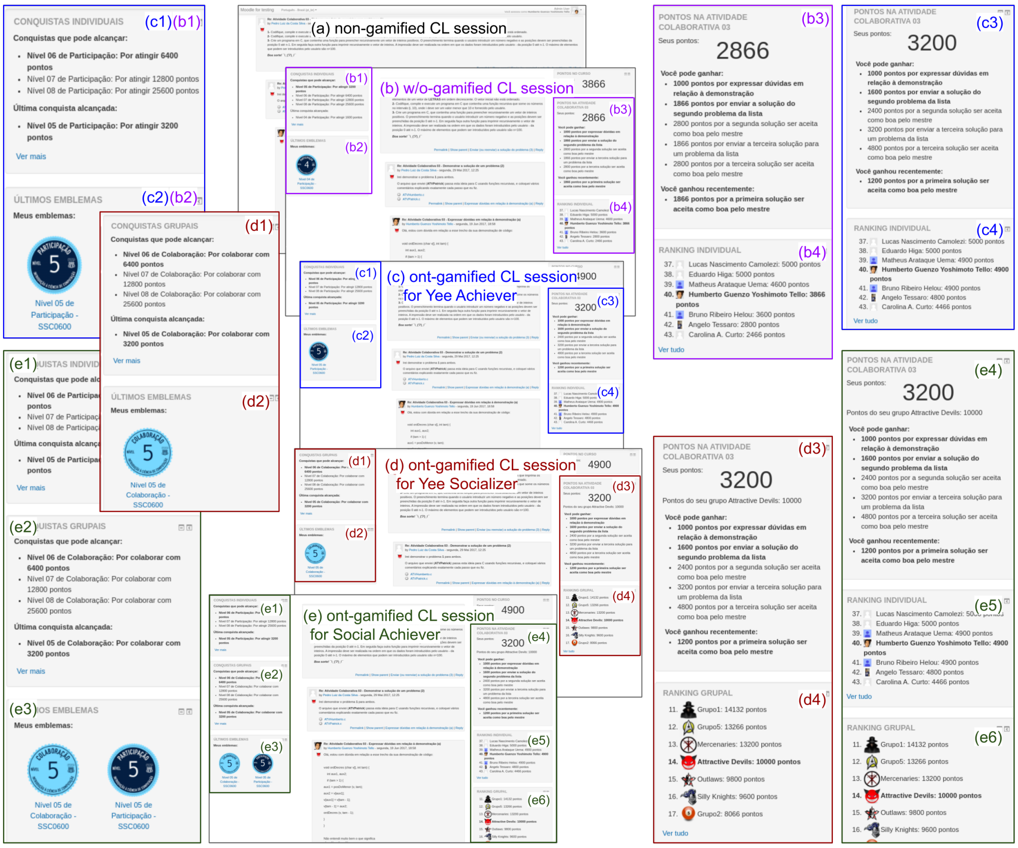

Fig. 3. Non-gamified, w/o-gamified and ont-gamified CL sessions for an apprentice student in the scripted CL based on the Cognitive Apprentice.

and Apprentice/Yee Achiever" and "*Gamified Cognitive Apprenticeship Scenario for Master/Social Achiever and Apprentice/Social Achiever*." Thus, students who like achievement-components and social-components were assigned to play the Social Achiever role in gamified CL sessions that promote a collaborative-competition, as exemplified in Fig. 3 (e) for an apprentice student. In this kind of ont-gamified CL sessions, the collaborative-competition is supported by individual achievements - shown in Fig. 3 (e1), and team achievements - shown in Fig. 3 (e2), with badges based on individual and collaborative participation - shown in Fig. 3 (e3). Point-systems for groups - shown in Fig. 3 (e4), a leaderboard with individual rankings - shown in Fig. 3 (e5), and a leadearboard with rankings for teams - shown in Fig. 3 (e6) support the collaborative-competition. In this 3rd empirical study, students who only like achievement-components were assigned to play the Yee Achiever role - as was detailed above and exemplified in Fig. 3 (c) for an apprentice student. W/o-gamified CL sessions - as exemplified in Fig. 3 (b) - are close/similar to the ont-gamified CL sessions for Yee Achiever. In both types of CL sessions, individual achievements with badges based on individual participation - as exemplified in Fig. 3 (b1) and (b2), individual point-system with a leaderboard with individual ranking support the individual competition - as exemplified in Fig. 3 (b3) and (b4). The only difference between w/o-gamified CL sessions and ont-gamified CL sessions for Yee Achiever is the value of points given as rewards for each interaction in the CL process. In w/o-gamified CL sessions, these rewards were defined by the teacher without using the GIMF model - as shown in Fig. 3 (b3), whereas these rewards were defined by the GIMF model in ont-gamified CL sessions - as shown in Fig. 3 (c3).

In the post-test phase, multiple-choice knowledge questionnaires and programming problem tasks were applied to the students to determine the learning outcomes of CL sessions as gains of skill/knowledge. During this phase, motivation surveys, IMI (Intrinsic Motivation Inventory) and IMMS (Instructional Materials Motivation Survey), were also applied for measuring the students' motivation as measurement of the intrinsic motivation (interest/enjoyment, perceived choice, pressure/tension, and effort/importance) and the level of motivation (attention, relevance, and satisfaction). These motivation surveys are well-known and broadly applied in the research community, and the reliability of these instruments was validated with a Cronbach's $\alpha = 0.894$ (IMI) and $\alpha = 0.909$ (IMMS).

Through two-way ANOVA tests and Tukey posthoc, we found significant differences in the students' motivation and their gains in skill/knowledge with relation to the type of CL session and the CL role played by students. Besides to perform these analyses with the scores obtained by the students through non-parametric and parametric tests, the estimates latent traits of motivation and gains in skill/knowledge were measured through IRT-models. Figure 4 only summarizes results of the statistical analysis based on the estimates from IRT-models. These results only correspond to the statistically significant difference found at the level of < 0.05 (p-adj), and with relevance for the claimed contributions described in this paper. Findings of the 1st empirical study were published in [Challco et al. 2019], and all scripts, instruments, data from experiments, and their statistical analysis are freely available at `http://bit.ly/2m6L7ko`, contributing to the open-access of knowledge and dissemination and validation of scientific results.

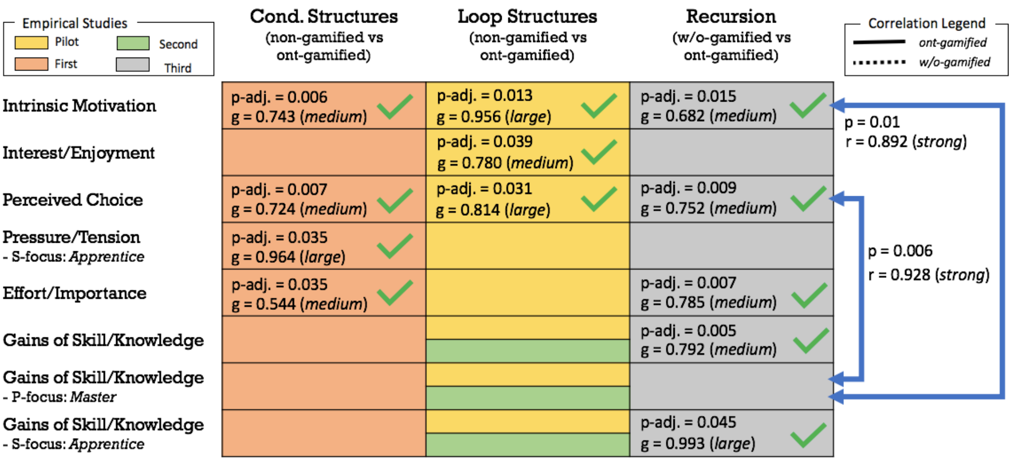

Fig. 4. Summary of statistical significance findings in the empirical studies.

In regards to the *effectiveness* for dealing with motivational problems, the results of the pilot, first and second empirical studies indicate that our approach, which creates ont-gamified CL sessions, have positive impacts on the students' intrinsic motivation and perceived choice if compared with non-gamified CL sessions. Furthermore, When the content was conditional structures, we had extra benefits related to the metrics pressure/tension and effort/importance to complete CL tasks. When the content was loop structures, in addition to the positive effects discussed previously, our approach has increased students' interest/enjoyment related to working in CL activities. About the *effi-*

ciency of dealing with motivational problems, results of the third empirical study indicates that the students' intrinsic motivation, perceived choice, effort, and importance were statistically significantly greater in when working in ont-gamified CL sessions (experimental condition) if compared with w/o-gamified CL sessions (control condition). Moreover, the gains of skill/knowledge obtained by students in ont-gamified CL session were greater than in w/o-gamified CL sessions.

Finally, the statistically significant results of Spearman's rank-order correlation tests in ont-gamified CL sessions show that the intrinsic motivation and perceived choice are strongly positively correlated with students' gains of knowledge/skill. This fact suggests that the improvement of learning outcomes in ont-gamified CL sessions was a consequence of the positive effects in students' motivation caused by the adequate personalization of game elements of our approach.

6. Conclusions and Contributions

Our main contribution has been to develop and empirically evaluate an approach to address, effectively and efficiently, the motivational problems that may occur in scripted CL. This result is highly relevant for the CSCL community that, in the past few years, has made efforts to find solutions to motivate and engage students when they work in collaborative tasks. To the best of our knowledge, this is the first approach that has been able to empirically demonstrate the benefits of ontologies and personalized gamification in students' learning and their motivation during scripted CL.

The practical implication of this contribution is that gamification now can be adequately and semi-automatically used as a good alternative to the current state of the art solutions that aim to motivate and engage students when working in CL activities. In particular, one of the benefits of our approach is that students without interest/desire to learn are positively affected. This benefit is ensured in our ont-gamified CL sessions by the proper alignment of pedagogical objectives with the individual motivational strategies, player roles, and game elements in the ontological structure to represent gamified CL scenarios. Another benefit of our approach is that, through the application of Persuasive Game Design (PGD), students can be motivated during the CL process to follow interactions patterns indicated in CSCL scripts. This benefit is ensured in our ont-gamified CL sessions by the proper connection between the PGD and the design of CL process that is represented in descriptive and prescriptive ways in the ontology OntoGaCLeS.

Our work also contributes to building the theoretical foundations of gamification. By demonstrating that, through our approach, we can obtain better intrinsic motivation than with current approaches, we provided strong empirical evidence that supports the need of using a tailored-based gamification approach instead of a one-size-fits-all approach. Furthermore, the positive effects of our approach on the students' gains of skill/knowledge with a strong positive correlation with the intrinsic motivation suggests that, to achieve the full potential and benefits of gamification, it is highly important to focus on the use of well-grounded theoretical knowledge extracted from theories and practices of gamification rather than only focus on building adaptive mechanisms.

We also offer a significant contribution to bridging the gap between two different communities, namely CSCL and gamification, that have been working to deal with motivational problems during the learning process. To do that, our formalization of knowledge that resulted in the ontology OntoGaCLeS has been essential. It brings practical and methodological implications. By employing the ontological structures (detailed in Chap. 3 and Chap. 4 of the thesis [Challco 2018]), we can represent the knowledge from game design and theories of motivation and human learning to build gamification models that support the personalization of game elements (e.g. personalization of game elements based on player type models). Based on our ontology, we built computational procedures and mechanisms to support the semi-automatic design of well-thought-out gamified CL scenarios. These procedures/mechanisms (detailed in Chap. 5 and Chap. 6 of the thesis [Challco 2018]) constitute an important contribution that aims to facilitate the development of a new generation of intelligent-theory aware systems to gamify CL sessions.

From a methodological perspective, our research work, briefly summarized in this paper, demonstrated that, through ontology engineering, we can identify and extract the necessary knowledge to properly gamify CL scenarios for dealing with motivational problems. Thus, employing the same research methodology of the thesis, we can extend the ontological structures of the ontology OntoGaCLeS to deal with other motivational problems that may also occur in other CL situations, such as peer-assessment, informal CL groups, and PBL (Problem-Based Learning). By reusing the ontological structures proposed in OntoGaCLeS, and employing our research methodology, new ontological structures can be built to solve other challenging motivational problems related to other research areas, such as individual learning, blended learning, project management, governance, and entrepreneurship.

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