An analysis of the Game Mechanics and Learning Analytics behind Pyramid collaboration scripts

René Lobo-Quintero
Department of Information and Communication Technologies, Universitat Pompeu Fabra
renealejandro.lobo@upf.edu

Davinia Hernández-Leo
Department of Information and Communication Technologies, Universitat Pompeu Fabra
davinia.hernandez-leo@upf.edu

ABSTRACT: Collaborative learning flow patterns (CLFPs) formulate good practices for scripts orchestrating activity sequences and collaboration mechanisms that can elicit fruitful social interactions. Despite their benefits, it is worth exploring how their implementation can be improved. Learning technology research suggests that the use of gamification strategies accompanied with learning analytics offers potential to reinforce the productive participation and collaboration between participants, and at the same time to help teachers to make regulation decisions and measure the impact of the activities. In this paper, we analyze three case studies where the Pyramid CLFP is used. The analysis shows that implementations of this pattern already incorporate different uses of game mechanics and learning analytics. The paper also discusses the approaches in use and how complementary mechanisms could be considered for the further improvement of future designs.

Keywords: Collaborative Learning, CLFP, Gamification, Learning Analytics, Pyramid, Scripts

1 INTRODUCTION

Collaborative Learning Flow Patterns (CLFPs) are topic-independent structures of potentially effective scripted sequences of learning activities that can be adapted to multiple educational scenarios (Hernández-Leo et al., 2006). These patterns can help teachers design and incorporate scripted collaborative learning scenarios into their teaching practice. Certainly, the application of CL poses certain challenges and drawbacks (Radkowitsch et al., 2020), such as (1) students usually divide the tasks, working individually without collaborating; (2) these activities require extra time for both teachers and students; and (3) can emerge eventual interaction and communication problems among students, and CLFPs largely contributes to overcome these challenges (Hernández-Leo et al., 2005), CLFPs achieve so through scripting mechanisms (in the formulation of groups, roles, resource sharing, and activity sequencing) that promote positive interdependence, individual accountability and knowledge sharing (Hernández-Leo et al., 2005, Johnson et al., 2016, Nah et al., 2014). Yet, given the relevance of their aims, additional strategies to reinforce CLFP effects on collaboration and learning are worth studying. In this paper, we explore how game mechanics and learning analytics can enhance the implementation of the scripting mechanisms in CLFPs.

On the one hand, previous research in game-based learning suggests that game mechanics can reinforce a pedagogical strategy able to support several underpinning CL mechanics present in CLFPs, facilitating higher levels of motivation, participation and more enjoyable learning experiences

(Johnson et al., 2016, Nah et al., 2014). Indeed, several studies have addressed the use of game-based learning in collaborative learning activities and environments. For instance, Darejeh & Salim, (2016) propose an ontology to represent gamification strategies in collaborative learning scenarios. Also, Johnson et al., (2016) describe a case study in which an online gamified discussion forum increased student collaboration and reduced response times. On the other hand, the implementation of game mechanics can benefit from the use of learning analytics (Freire et al., 2016). It is expected that the inclusion of game mechanics in the scripts based on the Pyramid CLFP generates key performance indicators so learning analytics can be applied to track and inform teachers about the learning process.

In order to tackle the objective of understanding how game mechanics and learning analytics can enhance the implementation of CLFPs, this paper focuses the study on a specific CLFP that incorporates key scripting mechanisms (dynamic changes in group formation - of increasing size - across a sequence of collaborative learning activities), the Pyramid CLFP (Hernández-Leo et al., 2006). The study is approached through an analysis, guided by the LM-GM framework (Arnab, et al., 2015), of three cases implementing the Pyramid CLFP as reported in the literature.

Thus, the research questions guiding this work are: (RQ1) What game mechanics are present in learning scenarios already implementing Pyramid CLFP scripts? (RQ2) How is learning analytics present in the implementation of Pyramid CLFP scripts? (RQ3) What can be proposed to extend game mechanics and the use of learning analytics in the implementation of Pyramid CLFP scripts?

The next sessions describe the background of the Pyramid CLFP, the LM-GM framework and the notions of gamification and learning analytics. Section 3 summarizes the three implementations of the Pyramid CLFP selected for the analysis. Then, section 4 presents the analysis of the game mechanics present in the selected cases and section 5 focuses on the analysis of the Learning Analytics used. Some proposals to extend the implementation of Pyramid CLFP using game mechanics are discussed in section 6.

2 BACKGROUND

2.1 Collaborative Learning Flow Patterns

Collaborative Learning Flow Patterns (CLFPs) represent broadly accepted techniques that are repetitively used by collaborative learning practitioners (e.g., teachers) when structuring the flow of types of learning activities involved in collaborative learning scenarios (Hernández-Leo et al., 2005). CLFP pre-structure collaboration in such a way that productive interactions are promoted, so that the potential effectiveness of the educational situation is enhanced (Jermann et al., 2004), fostering individual participation, accountability and balanced positive interdependence. Examples of CLFPs include Jigsaw, TPS (Think-Pair-Share), Simulation, TAPPS (Thinking Aloud Pair Problem Solving) and Brainstorming (Hernández-Leo et al., 2006). This paper is focused on analyzing Computer Supported Collaborative Learning (CSCL) studies that used the Pyramid pattern, which is a CLFP with complex scripting structures that cover key scripting mechanisms related to changes in group formation changing (in terms of members and group size) along a flow of several learning activities.

The “Pyramid” pattern is used for complex problems, usually without a specific solution whose process of resolution can benefit from a gradual discussion and consensus among all participants (Hernández-Leo et al., 2005). A Pyramid flow is usually initiated with individual students solving a global task. Then, in a second phase of the Pyramid, such individual solutions are discussed in small groups and agreed upon a common proposal. These small groups then form larger-groups iteratively and large group discussions will continue until a consensus is reached at the global level. Pyramid flows foster individual participation, accountability and balanced positive interdependence (Hernández-Leo et al., 2006). Furthermore, the Pyramid pattern promotes conversations in incrementally sized groups, clear expectations of reaching consensus and positive reinforcement mechanisms leading to desired positive behaviors in the learning process (Fluke & Peterson, 2013; Manathunga & Hernández-Leo, 2018).

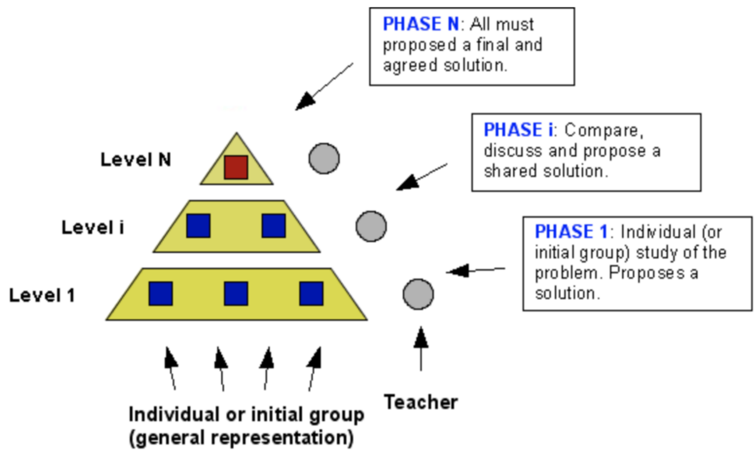

Figure 1: Pyramid CLFP (Hernández-Leo et al., 2006)

2.2 LM-GM Framework

According to Arnab et al., (2015). In gameful learning design one of the fundamental aspects consists in the translation of learning goals/practices into mechanical element of gameplay, “high-level pedagogical intents can be translated and implemented through low-level game mechanics”. To achieve this, first, they introduce the concept of Serious Game Mechanic (SGM) defined as the design decision that concretely realizes the transition of a learning practice/goal into a mechanical element of gameplay for the sole purpose of play and fun. SGMs act as the game elements/aspects linking pedagogical practices (represented through learning mechanics) to concrete game mechanics directly related to a player’s actions. Second, they propose the Learning Mechanics–Game Mechanics (LM-GM) model. This analytical model maps game mechanics and pedagogical elements that were abstracted from literature on game studies and learning theories.

The model helps to relate a set of standardized learning mechanics to another set of standard game mechanics. It allows for designers to investigate how the mechanics interact and to ensure that a system is grounded from a pedagogical and entertainment standpoint (Maarek et al., 2019), providing a concise means to relate pedagogy intentions and ludic elements within a player’s actions and gameplay (Arnab et al., 2015).

2.3 Gamification and Learning Analytics

Learning Analytics is the interpretation of a wide range of data produced by student's interaction in order to assess their academic progress, predict future performance and detect potential problems (Johnson et al., 2016). As stated by Gibson, (2017): data can "make it possible to gain highly detailed insight into student performance and their learning trajectories as required for personalizing and adapting curriculum as well as assessment".

In the particular context of game-based learning the use of learning analytics has been barely explored. By monitoring and analyzing gamification related data, experts can gain valuable insights and take corresponding actions towards goal achievement. Relevant data sources comprise user behavior data, user properties, and progression data (Heilbrunn et al., 2017).

Freire et al., (2016) explore the concept of Game Learning Analytics (GLA), its tools and technologies. Having data of what is happening while the user is playing is key to relating game-play with actual learning, and to move from only theory-based approaches to more data-driven or evidence-based approaches.

Additionally, other previous publications also explored the use of LA in gamification environments. For instance, the literature review performed by (Trinidad et al., 2018) shows the lack of tools that can provide gamification experts with real-time analytics from gamified systems, so experts can evaluate, improve and adapt their gamification strategies.

2.4 Related work

Previous studies have analyzed the effects of applying the LM-GM framework in the design of game-based learning applications. Callaghan et al. (2016), developed a case study where they applied the LM-GM in the design process of a serious game to teach electrical and electronic circuit theory. The objective of the game was to solve a series of circuit problems in stages, where the player explores each puzzle (behavioral momentum), tries to understand its structure and how to efficiently solve the problem using a simulate/response approach to observe, experiment and analyze circuit behavior under time constraints. The end of each level provides feedback to the player on their progress (score achieved), possible rewards (achievements) and competition (leader boards).

Baldeon et al. (2016), created 3DVirtualPC a serious game designed to develop computer literacy skills, such as the identification and analysis of concepts related to basic hardware components of a computer. To do so they made a mapping of the learning objectives, learning mechanics, game mechanics, and bloom taxonomy categories in order to decide the best implementation and in-game action.

However, to the best of our knowledge, none of the previous studies have addressed the use of the LM-GM framework in CLFPs, their pre-established features that can be gamified (e.g., phases, relevant expected student actions), and the gamification analytics required to monitor the students' actions supporting collaborative learning.

3 SELECTED IMPLEMENTATIONS OF PYRAMID CLFP SCRIPTS

In order to identify the relevant gameful characteristics presented in the Pyramid CLFP an analysis of learning - game mechanics and learning analytics used in diverse applications of the Pyramid CLFP was conducted. Three papers that report case studies that apply Pyramid were selected considering the following criteria: 1) they report explicit implementations of the Pyramid pattern, 2) they provide sufficient details of the learning design of the script, 3) the paper reports the use of learning analytics, 4) the study associated to the script is consolidated (i.e., vs. work in progress), 5) the three papers are written by different authors.

The application of these criteria led to the selection of the following journal papers:

Case 1. "Monitoring pattern-based CSCL scripts: a case study" by Rodríguez-Triana et al., (2011), which proposes a method to get an automated and higher level view about the evolution of the learning process structured by a CLFP to enable the monitoring of the collaboration.

Case 2. "Design of a Competitive and Collaborative Learning Strategy in a Communication Networks Course" by Regueras et al., (2011), presents a study using the tool QUESTOURnament that combines competitive and collaborative learning approaches in order to motivate students and improve their learning process.

Case 3. "Authoring and enactment of mobile pyramid-based collaborative learning activities in this paper" by Manathunga & Hernández-Leo, (2018), which proposes a particularization of the Pyramid CLFP to support flexible and scalable collaborative learning scenarios through the tool PyramidApp providing a web-based editor and an enactment environment accessible through web or mobile devices.

A summary of the main elements of each case can be found in Table 1.

Table 1: elements of each paper.

Sample	Learning design implementing the Pyramid	Additional tools	Observations
Case 1: 46 students of a third-year course (out of five) on "Network traffic and Management", s Engineering degree.	Two-level Pyramid CLFP. At level-1, groups of 2 participants attended a face-to-face lab session, students had to draw a preliminary version of a sequence diagram and write a report with a summary of the main decisions and issues. At level-2, groups joined in super-groups (composed of 4 groups). Each group had to review and provide feedback on the reports produced by their super-group mates; then, they had to discuss and produce a joint version of the diagram, and perform an oral presentation with a common version of the conclusions.	Students were provided with a shared board (Dabbleboard), and in order to explain, review and discuss, they had at their disposal shared documents and presentations (Google Documents and Google Presentations). Since these tools cannot be automatically integrated in Moodle the GLUE! Architecture (Alario-Hoyos et al., 2013) was used to integrate them into the VLE.	The authors reported some critical situations like for example that in a group, just one of the group members interacted with the resources or that in another group none of the participants had accessed the resources. Also, students complained about the lack of information about their mates' work, which forced them to connect and review their resources frequently to check whether there was any change.

Case 2: 36 students from an undergraduate communication networks course, part of the core curriculum of the three-year degree in an engineering program.	Two phases script: a 3 level pyramid and a competitive second phase. Initially at level-1 the students studied the class material individually, in the level-2 the students were grouped in pairs in order to prepare questions about one of the specific topics and add them to a wiki, in the level-3 the whole group participated in a discussion and selected the six best questions. In the competitive phase pairs students compete in order to answer the questions posed and then assessed by other students. Finally, the score for all of the work for each pair of students is calculated, taking into account both the score obtained for their answers and the assessment mark.	Moodle e-learning platform as a collaborative framework. Competitive active e-learning tool called QUESTOURnment, which is integrated into the Moodle platform. QUESTOURnament allows teachers to organize contests in both individual and group work environments. Each contest includes a set of intellectual challenges or questions that must be solved by the students within a certain time limit. The answers are rewarded by means of a variable scoring system, students can also submit new questions and assess the corresponding answers.	Throughout the experimental study, the teacher observed the learning process, reviewing both the proposed questions and the assessments of the answers, in order to guarantee the quality of the questions and the fairness of the assessments. In general terms, the students considered that it was easy to reach agreement. However, it was more difficult for them to pose questions and to assess the answers of their classmates, which is understandable since this is usually done by teachers and not by students.
Case 3: first-year undergraduate students (n = 194) taking an Introduction to Information and Communication Technologies, second-year students (n = 43) taking Network Protocols and Masters' students (n = 46) (several engineering programs) taking Research Methodology	Most of the PyramidApp rounds were conducted in f2f scenarios with different kinds of level configurations (all Pyramid activities having an individual level and one or two group levels). Two sessions (one with the first-year and another with the second-year) were enacted using the distance mode of the application. In a distance mode, students were receiving emails notifying about the activity progress, avoiding the need to be online all the time.	PyramidApp: a web-based scalable, dynamic collaborative learning application. that is used to orchestrate activities in which participants can express their individual solutions to a task followed by cumulative negotiations in increasingly larger groups (Pyramid levels) to select the most appropriate solution. The orchestration is done automatically considering the pedagogical constraints of the CLFP and a set of mechanisms that achieve flexibility in terms of flow dynamism and scalability.	Some students missed the initial submission phase due to either late access or ignored timing values instructed in the email. Several students could not submit options or rating timely as they were not paying attention to timer notifications. Some groups used the chat feature extensively while some did not Further investigations would be interesting for improving usage of discussion features.

4 GAME MECHANICS PRESENT IN PYRAMID CLFP SCRIPTS

For each paper an analysis of learning mechanics using the LM-GM framework was performed to identify the learning mechanics and the game mechanics that were applied in the scripted activity.

In case 1, the authors implemented a 2 level pyramid with face to face and virtual activities, the mapping of learning mechanics - game mechanics (Figure 3) shows that the script using a 2-level pyramid presents 8 of the 38 game mechanics. Students had to collaborate and cooperate with their peers to design a sequence diagram, then they had to provide feedback to the other groups, and in a process of communal discovery they created a joint version of the diagram.

Learning Mechanics			Game mechanics			
Instructional	Guidance		Behavioral momentum	Role play		
Demonstration	**Participation**	Action/task	**Cooperation**	**Collaboration**		
Generalization/ discrimination	Observation	**Feedback**	Selecting / collecting	Tokens	Goods / information	
	Question & answer			Cascading information	Cutscenes / history	
Explore	**Identify**	**Discover**		**Questions & answers**	**Communal discovery**	
	Plan	Objectify	Strategy / planning	Resource management	Pareto optimal	Appointment
Hypothesis	Experimentation		Capture / eliminate	Tiles / grid	Infinite gameplay	
	Repetition		Game turns	Action points	Levels	
	Reflect/discuss	**Analyze**	Time pressure	Pavlovian interactions	**Feedback**	
	Imitation	Shadowing		Protégé effect	Meta-game	
Simulation	Modeling		**Design/editing**	Movement	Simulate / response	Realism
Tutorial	Assessment		Tutorial	Assessment		
	Competition			Competition		
Motivation	**Ownership**	Accountability	Urgent optimism	**Ownership**		
	Responsibility	Incentive	Rewards / penalties	**Status**	Virality	

Figure 3: Learning and game mechanics in case 1 (elements in blue cells)

The use of a competition phase after the 3-level pyramid in the script used in case 2 added new learning and game mechanics, resulting in a total of 11 of the 38 mechanics included in the LM-LG framework (Figure 4). Students initially had to cooperate and collaborate to prepare questions about the studied topic and post them in a wiki, then in a communal discovery phase they had to select the six best questions, this created a sense of status and ownership between the students. In the competitive phase they had to compete to be the first to answer in a given period of time, having a second type of feedback which took into account both the score obtained for their answers and the assessment mark.

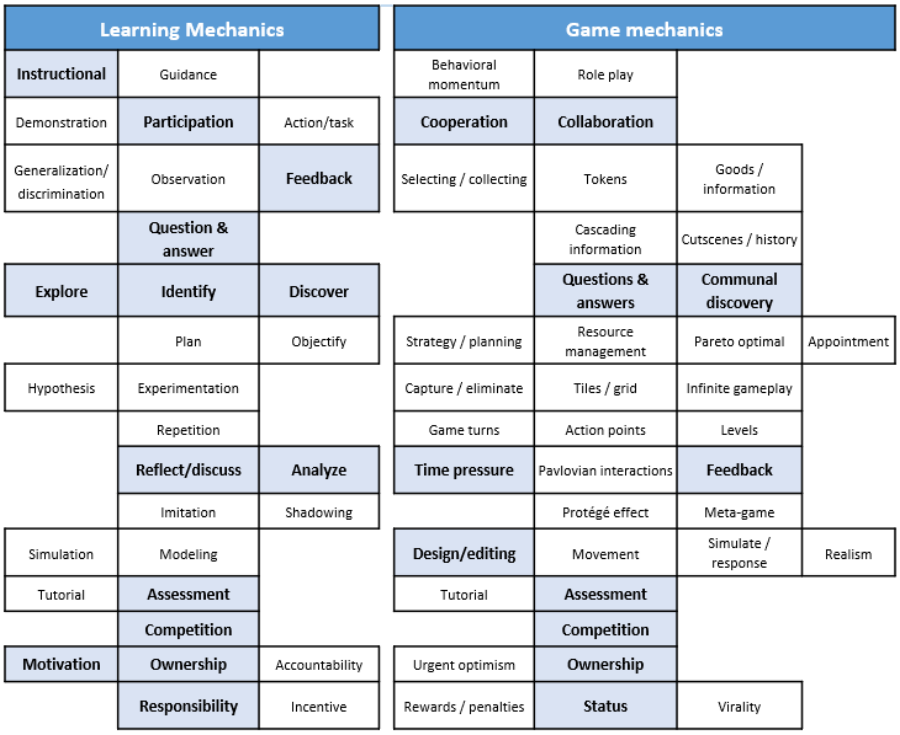

Figure 4: Learning and game mechanics in case 2 (elements in blue cells)

In case 3, the mapping is similar to the one obtained for case 1, with 9 of the 38 game mechanics (Figure 5). The addition of a level in the pyramid increased the amount of feedback received. Moreover, the use of a dedicated application that had a time limit to send the answers corresponds to the time pressure game mechanic).

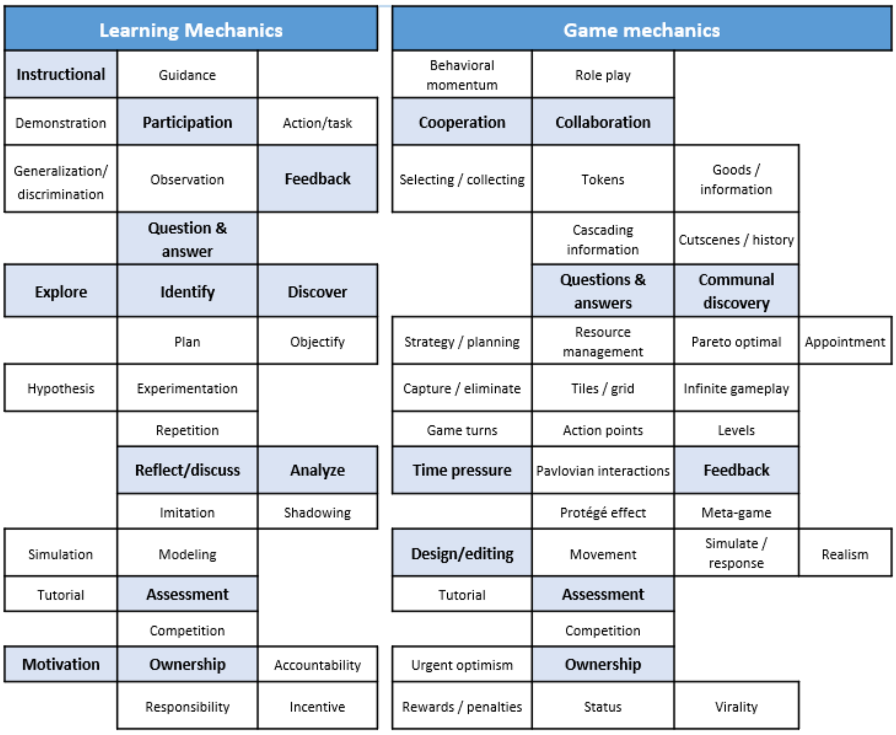

Figure 5: Learning and game mechanics in case 3 (elements in blue cells)

5 LEARNING ANALYTICS PRESENTED IN THE IMPLEMENTATION OF PYRAMID CLFP SCRIPTS

Each case had scripting mechanisms using CSCL tools that helped the enactment of the activities and allowed teachers and researchers to track the learning process. In this section we report an analysis of the learning analytics used in the cases, and how they relate to the different game mechanics.

In case 1, the authors retrieve and analyze the content of GLUE's logs, Moodle and Google docs event history (Table 2) in order to detect evidence of the key collaborative aspects that were previously estimated in the design of the activity, this analysis done during the enactment phase detected some potentially critical situations in the collaboration that were informed to the teachers in order to take preventive measures. The extracted data is related to the following game mechanics: cooperation, collaboration, design/editing and communal discovery.

Table 2: Learning Analytics data presented in case 1.

Tool	Source	Data
Google docs tools	Document revision history	User, date, time and document version
Moodle	Event history	Date, time, IP address, user name, action, resource used
GLUE!	Access History	Event logs user, date, time, resource accessed

Case 2 used a system integrated in the Moodle platform that allowed students and teachers to track the progress of the activity, showing the top ranked groups and their mark, students also could see the questions posted by others and their date (Table 3). In this case, the monitoring process was done manually by the teacher, however the gathered data along with a questionnaire that students had to answer at the end of the activity, was used to perform an analysis of the results comparing them with the ones of the subject in previous years.

Table 3: Learning Analytics data presented in case 2.

Tool	Source	Data
QUESTOURnament	history	User, date, time, assessment mark, final score, time used
Moodle	Event history	Date, time, IP address, user name, action, resource used
Wiki	Public data	Answer submitted, author, date
Survey	Answers	Work of the other groups, experience, perception of acquired learning

In case 2 the data gathered is mainly related to the competition and time pressure game mechanics, With the information from the questions posted on the wiki and the event history of QUESTOURnament the whole competition can be tracked, also the collaboration and cooperation game mechanics could be studied from the Moodle event history.

Case 3 used a dedicated application (PyramidApp) to help teachers in the design and enactment phase, during the activity students had to rank the different answers with a scale of 1 to 5 and could see which answers were promoted to the next level of the pyramid. The data gathered was used to track if the collaboration conditions were met (reach common goal, positive interdependence, coordination and communication, individual accountability, satisfaction).

Table 4: Learning Analytics data presented in case 3.

Tool	Source	Data
PyramidApp	logs	answers, chat logs, answer's score, time expended, ranking of the answers, users that submit
Survey	Answers	experience perception

In case 3, all the game mechanics presented in the script can be studied thanks to the use of a dedicated application that registers all the interactions during the enactment of the activity. The logs contain key information of the different participations during the script that can be used to develop a collaboration and cooperation measure. Also, the chat logs and the ranking of the answers can be used to track the game mechanics related to the status between the students and the ownership of the answer.

6 WHAT CAN BE PROPOSED TO EXTEND GAME MECHANICS AND THE USE OF LEARNING ANALYTICS FOR THE IMPLEMENTATION OF PYRAMID CLFP SCRIPTS?

The three case studies analyzed share common observations, for example: (1) in some groups the collaboration between participants was not as successful as expected (2) participants only interacted with some of the materials (3) participants did not submit their answers the given time. As shown in the LM-GM analysis, the Pyramid CLFP scripting implementation already incorporates a significant number of game mechanics. Yet, the analysis also shows that it is still possible to consider additional mechanics which has a potential to further improve the implementation of the pattern, e.g.:

- Use of a meta-game system that includes some of the classical elements of gamification (points, badges and leaderboards) linked with an in-course reward system can be a way to increase the level of interest and collaboration (Ortega-Arranz et al., 2018). The use of a competition system is optional but encouraged as reported in the second paper its application reported very good results. This meta-game will also generate analytics that can be used to track the level of engagement that the students have in order to help the teachers to take action

- Depending on the nature of the subject and the learning objectives, this can be augmented into a full role-playing gamification system, where students assume different roles (their progress might be also linked to an avatar) the success in the activity depends on the collaboration of the different roles with different characteristics. This game mechanic is very aligned with the "distribution of roles" mechanism present in several collaboration scripts, and it is known it can contribute to fostering positive interdependence, individual accountability and knowledge sharing (Kobbe et al., 2007), while at the same time creating more data variables to analyze and help teachers to track the achieving of the learning objectives.

7 CONCLUSIONS

Despite the increasing number of works in gamification, learning analytics and collaborative learning it is unclear to what extent there is or there could be a game-based perspective in the implementation of CSCL scripts, such as those structured according to the Pyramid Collaborative

Learning Flow Pattern. This paper analyses the integration of game mechanics and learning analytics in three reported case studies and shows that several game mechanics are present in the implementation of the Pyramid CLFP, such as collaboration, cooperation, competition, assessment, feedback, Communal discovery, status and ownership. Learning Analytics is used in the three cases, to track the learning process, determine the cooperation and collaboration levels and to inform the teachers about negative situations that could emerge during the activity. Game mechanics not considered in the cases include roleplay, rewards/penalties, history, levels and movement.

As future work, we plan to carry out co-design activities with teachers interested in using gamification in CLFPs in their teaching practice and evaluate the effects of their implementation with students. This will help us know (1) whether diverse game mechanics are seemed suitable for incorporation in learning designs involving playful CSCL scripts; (2) analyze whether the gamification strategies implemented actually contribute to further fostering positive interdependence, individual accountability and knowledge sharing, (3) determine which learning analytics would help practitioners in the design and delivery of the scripts.

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