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Gamifying teacher professional development: an experience with collaborative learning design

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Abstract. Despite wide-scale uptake of gamification in professional training generally, application in Teacher Professional Development (TPD) is still in its infancy. The few experiences reported hitherto mainly concentrate on fostering participation and engagement in the training intervention itself. By contrast, we believe that gamification of TPD can and should have a broader scope, helping to enhance teachers' motivation to apply newly acquired knowledge and approaches in their daily practice. Accordingly, we have sought to gamify an existing TPD environment called 4Ts, which encourages teachers to design collaborative learning activities for their students via a specific theoretic approach (4Ts). In this paper, we describe the selection and integration of gamification mechanics in 4Ts following an existing methodology that, while generic, has nonetheless proved useful for gamification in the education field. The paper illustrates both the methodology and the experience of gamifying 4Ts with a view to potential transferability to similar, educational contexts.

Keywords: Gamification, Learning Design, Continuous Professional Development

1 Introduction

One of the issues frequently highlighted in the Technology Enhanced Learning field is that promising innovations proposed at research level often fail to be taken up in teachers' daily practice [1, 2, 3, and 4]. This is even the case when teachers participate in professional training initiatives intended to facilitate and foster such appropriation.

The lack of widespread systematic uptake is keenly felt in the Learning Design (LD) field, where, in spite of more than a decade of research [5], tangible impact on consolidated teaching practice remains hard to demonstrate [6, 7]. Research on LD aims to foster the adoption of systematic and pedagogically informed approaches to the design of learning activities with an emphasis on a participatory logic based on

sharing and reuse of design artefacts. Over the years, this effort has led to the development of a number of LD tools, each intended to support the three main phases of the design process (conceptualization, authoring, and implementation and delivery to learners) and to support and scaffold communities of (co)designers [6, 8, 9]. When rolled out from the context of the research projects in which they were developed, these tools have tended to attract positive initial reactions from teachers, but have largely failed to gain general acceptance as an integral part of their praxis [6, 10, 11].

In particular, as far as the design of collaborative activities is concerned, there is also a claimed lack of methods and tools able to support the conceptualization phase [12, 13]. This was clearly confirmed in a European TEL workshop organized by the STELLAR Network of Excellence in 2011 [14]. Attended by researchers in Learning Design and Computer Supported Collaborative Learning (CSCL), the event has held in specifically to address this perceived obstacle. On that occasion, in an attempt to address the above mentioned gap, a model was proposed which at the time was called the "3Ts model". Following the intensive follow-up discussion within the workshop community springing from that event, the model was refined and further enriched [15, 16], leading to its eventual renaming as the "4Ts model".
Later on, the model was also reified in a "4Ts design environment", i.e. a "half-baked" paper-based game, which was then experimented in the context of a teacher training initiative [17]. The experiment provided very positive and promising results [13], encouraging further developments of the design environment.

As already mentioned, though, currently the "4Ts design environment" is not a fully-fledged game, as it consists of a board, a number of different card decks and people playing in groups by manipulating the cards according to rules. Still, in this preliminary shape, the 4Ts design environment was able to meet teachers' need to learn how to design effective collaborative activities, by getting gradually familiarized with the most common collaborative techniques and experimenting collaboration and co-design with peers [13].
This is an encouraging start but in order for the 4Ts environment to meet our overarching objective of impacting on teachers' professional practice, we believe that it needs to be 'levelled-up' from a game-like system to a fully-fledged game, complete with appropriate game and gamification mechanics. We posit that this is a precondition necessary to generate intrinsic motivation - in terms of Autonomy, Competence and Relatedness [18] – at levels sufficient to make teachers' systematic take-up a real possibility.
In order to explore whether our assumption is correct, we have decided to add a gamification layer to the present 4Ts environment. To do so, we have opted to follow an existing 'generic' gamification methodology that was originally intended for gamifying processes in the Knowledge Management (KM) field.

In this paper, we describe our "gamification experience", i.e. the process we underwent to gamify our initial 4Ts environment.
Thus, the paper, after providing a theoretical background for the work, describes our initial "4Ts design environment", then presents the 'generic' gamification

methodology chosen to 'gamify' the 4Ts, and then illustrates how we applied the methodology in our context.
As a result, the paper, without having the ambition of evaluating the overall experience, wants to provide a contribution to the gamification research field, by stressing strengths and weaknesses of the adopted methodology, in view of possible further application of the same methodology to similar educational contexts.

2 Theoretical background

The body of literature in the fields of gamification, serious games and game based learning is increasing rapidly, as is the number of papers dealing with the specific topics of designing gamified experiences and/or environments. Despite this, or indeed as a result of it, there remains a certain degree of dispersion in terms of shared solutions or practices.
Among the various reviews and analyses published in recent years, one interesting systematic literature review on games-based learning and serious gaming can be found in [19]. More recently, [20] analyzed a number of studies and identified research threads that are yet to be covered.

Among the burgeoning wealth of studies on gamification, this section deals with those that have directly influenced the experience presented in this paper.
To begin with, the work by [21] has providing great inspiration, as the author identifies a number of game elements and associates them to different game typologies. Among these, those that turned out to be most relevant for our 4Ts work include:

- Games aimed at triggering problem solving skills and creativity. According to [21], key elements that should feature in games of this type are: assuming roles, fostering meaningful dialogues, proposing challenges, manipulating variables, and providing authentic environments. As described in the following, these game elements will become parts of the 4Ts environment.
- Problem solving games, i.e. games aimed at focusing players' attention on one problem and getting them to elaborate possible solutions. This is also the case with 4Ts, as we want teachers to find innovative pedagogical solutions to the problems they face in their (classroom) practice. For these kinds of situations, [21] suggests creating shared purposes among players, allowing individual and team efforts, creating a community around the game.
- Conceptual knowledge-based games. 4Ts is designed to get teachers to learn some theoretical concepts basically related to collaborative learning. Possible game ingredients in this case include: experiencing the concepts, providing examples and non-examples, etc.
- Rules-based games. Ingredients that might deserve attention in this case are: proposing role playing, getting players to experience consequences, using board games, etc.

Other researchers have proposed game mechanics and game dynamics classifications [22, 23]. Some studies have focused specifically on gamification mechanics that can be applied in teaching/learning contexts: [24], for example, provides a list of gamification elements explaining how they could be included in an e-learning course; [25] proposes another list of gamification elements, focusing specifically on social game mechanisms; [26] propose other gamification mechanics as they were used in the context of an online university course.

To the best of our knowledge, though, few reports have been published about gamification applied to teacher training contexts and, in the few examples we know of [27, 28], it was mostly aimed at fostering teachers' participation and engagement in the training intervention itself, rather than in supporting the transfer to praxis.
By contrast, we believe that gamified approaches to teacher training could serve the purpose of enhancing intrinsic motivation to adopt innovative approaches in daily practice. Thus, we have turned to theoretical models that expressly target motivation in the field of teaching and learning, such as the ARCS Model [29]. According to Keller, there are four key elements in the learning process which can encourage and sustain learners' motivation, namely Attention, Relevance, Confidence and Satisfaction (ARCS).
While ARCS is often used to create e-learning and courseware [21], [30] identifies elements that "make things fun to learn", namely: Challenge, Fantasy and Curiosity.
Lastly, Self-Determination Theory (SDT) by [18] is a macro-theory addressing the factors that either facilitate or undermine motivation, namely Autonomy, Competence and Relatedness.
Given the centrality of the intrinsic motivation construct in our context, in the end we chose to adopt – among the existing gamification methodologies and guidelines – the one proposed in [31]. This fits particularly well with our context, because the authors identify game mechanics starting from Autonomy, Competence and Relatedness, i.e. from the main principles driving intrinsic motivation according to the SDT.

3 The initial "4Ts design environment"

Before examining the adopted gamification methodology and its application to our context, it is necessary to first briefly describe our original environment, namely 4Ts.
As mentioned, this environment is based upon the corresponding 4Ts theoretical model, which assumes that any activity in a collaborative learning situation can be regarded as a task to be accomplished by one or more teams of students within a certain timeframe in a given technological environment [14, 15]. Consequently, the model identifies Task, Team(s), Time and Technology (the 4Ts) as the dimensions of a collaborative learning activity [13].
When designing a collaborative activity, a teacher will inevitably end up working with these four interrelated components, progressively taking decisions about each one and its place in the overall design space. Each decision taken for one component will ineluctably affect the decisions that are or can be taken for all the others. As a means of support in this difficult task, the teacher can draw on the notion of

"collaborative techniques", i.e. predefined patterns drawn from established and effective praxis, that entail certain predetermined (or at least recommended) combinations of Tasks, Teams, Technologies and Time.

Thus, the 4Ts environment is essentially composed of a board, where the Time component and its sub-division in time units (e.g. weeks) is represented in the form of an empty grill (the design space), and a deck of cards in 5 different 'suits':

- Task cards (red suit): one card for each of the 10 different Tasks, with multiples available (total 40 Task cards);
- Team cards (yellow suit): one for each of the 6 Team types, with multiples available (total 24 Team cards);
- Technology cards (green suit): one card for each of the 8 Technology types, with multiples available (total 32 Technology cards);
- Technique cards (blue suit): one card for each of the 15 Technique phases, with multiples available (total 15 Technique cards);
- Wild cards (white suit): a set of 9 blank cards that players can complete and use on the fly as a personalized card in any of the four color suits.

The Task, Team and Technology cards all have the same structure (see fig.1). On the front, each card contains a title and a brief description of that particular item, while on the back is a set of suggestions specifying relations between that item and cards in each of the other suits, i.e. indications on cards that combine well with that one.

The 'game' is intended to be played by teachers/designers working in groups around a table. The aim is to construct a design containing one or more learning activities by positioning suitable combinations of cards on the Time board to form a coherent description of an effective learning intervention [13]. The nature and boundary conditions for that intervention plan (contents, objectives, context) may be set by a "game master" or determined by the team itself. To construct the plan on the board, players analyze the cards, consider the suggested relations among them, and decide on suitable card combinations, shifting these about on the board until they find an arrangement that satisfies all the team members (see fig. 2).

As mentioned, the lack of fundamental game mechanics means that the 4Ts prototype environment cannot be considered a fully-fledged board game as such. Nevertheless, it does embody some game aesthetics (the board, the cards, embedded rules), not to mention team-based interactions, which are reminiscent of game-like activities. As mentioned above, these aspects alone can benefit motivation. Nonetheless, as indicated at the beginning of the paper, further steps are required to endow 4Ts with a more game-like nature such that it might enhance teachers' intrinsic motivation to make (collaborative) learning design, based on the 4Ts model, an integral part of their daily practice.

Fig. 1. Examples of 4Ts cards (front and back of a Task and a Technique card)

Fig. 2. Teachers designing with the 4Ts environment

In the following section, we describe the general methodology we chose to further gamify the 4Ts environment.

4 A methodology for gamification

The adopted methodology was originally proposed by [31] as a framework for the gamification process in Knowledge Management (KM) contexts.

As illustrated in Figure 3, it comprises three macro-phases: Analysis of the Game Environment; Game Environment; Measurement and Evaluation.
Phase 1 encompasses definition of the aims of the designing organization (business objectives), which entails analyzing the target users and their needs with particular regard for extrinsic and intrinsic motivation. Phase 2 entails defining the main game mechanics and dynamics and designing the overall game experience. As already mentioned, the identification of game mechanics in this phase is driven by, and built upon, the notions of Autonomy, Competence and Relatedness, in accordance with the SDT [18]. In Phase 3, indicators and metrics are identified to measure whether the main objectives and needs defined in Phase 1 have been met.

The three phases are intended to be implemented in a cyclical fashion, allowing for adjustments at various stages during the design process (see Fig. 3). A complete overview of the proposed methodology is provided in [31].

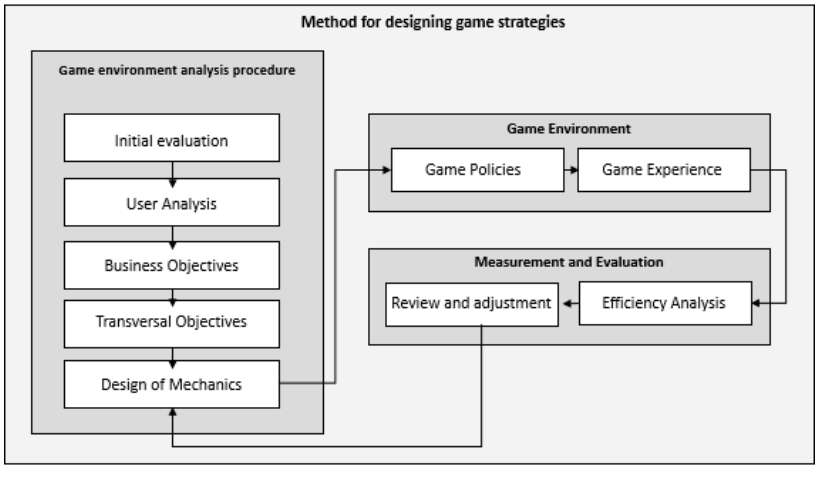


Fig. 3. Gamification methodology proposed by [31].

5 Applying the gamification methodology to the 4Ts

In this section, we describe how the general-purpose methodology described above has been applied in the specific context of the 4Ts environment and the results of that application.

Step 1 – Analysis of game environment
The initial analysis of the game environment ("Initial evaluation") was conducted by a researcher from the team responsible for the gamification methodology (hereafter referred to as the "Game Designer" = GD) working in close collaboration with the researchers who developed the 4Ts environment (the "4Ts Team" = 4TT).
A preliminary brainstorming between the GD and 4TT was held to gain reciprocal understanding of the respective constructs in their present versions. On that occasion, a demo session of 4Ts was held to illustrate how it worked. Subsequently, the GD conducted individual interviews with 4TT members to collect data about the intended target users and the main game objectives envisaged.
A key requirement emerging from this preliminary diagnosis was that the envisaged gamification layer for the 4T environment should be as simple as possible and not add too much complexity, to avoid cognitive overload for users.
Furthermore, it was agreed that the proposed game mechanics should be aligned with the existing elements (i.e. boards, cards) and should be consistent with the overarching aims of 4Ts in promoting reflective, pedagogically-aware learning design

practices. For example, the mechanics should not reward speedy design, as this could impoverish both the team-based interaction and, ultimately, the quality of the design produced.

The "User Analysis" phase comprised two focus group sessions with two different prospective user samples: a group of six teachers who were new to collaborative learning strategies and a group of twelve expert learning designers. Each engaged in a full cycle of design with 4Ts and subsequently provided feedback on the experience. The aim was to gather data, from both activity monitoring and from the feedback, that would further understanding of practitioner needs, expectations and motivations, and that might also provide insights into the potential adoption of the 4Ts environment in daily practice.
The two sessions both began with a theoretical introduction to collaborative learning strategies (obviously more extensive for the group of teachers new to the topic) and a presentation of the 4Ts environment. Subsequently, the participants were divided into groups for the practical activity (two groups in the case of the teachers, three for the designers) and asked to use the 4Ts board and cards to design a collaborative learning intervention. Moderators were on hand to provide support where requested.
Each of the groups was recorded during the design process and the videos were later analyzed to detect patterns of use and behavior. At the end of the design session, a meta-plan activity was held to collect participants' impressions about the environment and also to gather input regarding possible ways in which the prototype version of 4Ts they had used might be enhanced through gamification and the integration of digital capabilities.
All the data collected from the two focus groups were then analyzed by the GD, who captured user needs in the form of a set of Persona Cards [32]. These are like 'identity cards' that describe prospective "average users" of the 4Ts game; an example is shown below in fig. 4.

At this point, it was also possible to define the main "Business Objective" for the game. This was done by the GD, who negotiated the definition with the 4TT.
In the end, the Business Objective of the game was stated as it follows:

"The 4Ts game aims to support teachers in the conceptualization of pedagogically informed collaborative learning activities for their students."
This provided the basis for definition of the Transversal Objectives, described in this way:

- "Through the 4Ts game, users will learn how to design pedagogically informed collaborative activities based on the 4Ts model".
- "Through the 4Ts game, users will experience and appreciate collaboration among peers by co-designing collaborative activities for their students"
- "Through the 4Ts game, users will start to integrate the 4Ts model into their daily design practice".

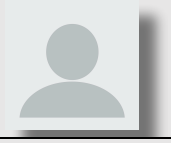
PERSONA CARD 	**Name:** Mario Rossi **Gender:** M **Age:**45 **Nationality:** IT **Profession & school level:** teacher in primary school
Prior experiences	Mario has been a science teacher since 10 years and thus has developed a certain experience as far as applying traditional teaching approaches to classes. He is curious and in general attracted by novelties, even if he has not so much experience in innovative pedagogical approaches.
Role and responsibility	Science teacher in a primary school. At the moment, he is responsible for two classes.
Competence and skills	As far as technologies are concerned, is an "average user", not really expert as far as the use of ICT in teaching and learning activities, but able to use basic ICT tools to manage his personal stuff.
Motivation and drivers	He wants to improve his teaching style; the main driver for his change is the increase of foreigner students in his classes. He now understands that his traditional teaching methods are not enough anymore to tackle the ever-changing and complex learning environment of his classes. He hopes collaborative learning approaches can help. At the same time, he is a little afraid of innovation, also because so far he has not shared his concerns with other colleagues (in his school he suffers some kind of isolation).
Objectives and expectations	He would like to apply collaborative learning to his classes, especially with inclusive purposes.
Obstacles	He perceives as potential obstacles the following factors: his isolation in school, low flexibility of school organization, not many technologies available in the school.
Other notes	--

Fig. 4. Example of a Persona Card resulting from 4Ts User Analysis

Step 2 – Game environment

During this stage, the GD worked in collaboration with the 4TT to develop a preliminary hypothesis about the main game mechanics to include, taking on board the results of the previous stage. This was carried out in an iterative way, with both face-to-face and online interactions.

One of the aspects that emerged quite early (see Persona Card) regards a particular characteristic of the target population, i.e. their resistance to competitive approaches in peer interaction and their likely reluctance to some very common game mechanics supporting extrinsic motivation. As Kapp suggests [21] (pg. 93), "there are a number of problems with pure extrinsic motivation from an instructional perspective", among

Table 1 – Objectives, SDT elements and game mechanics in the 4Ts game.

Transversal Objectives	SDT elements to support motivation	Game Mechanics
Learn how to design pedagogically informed collaborative activities based on the 4Ts model	Autonomy	Interaction with the system is organized in "levels"; the player team is proposed a structured sequence of design tasks that increases in difficulty. The system initiates the game by providing the player team with a subset of cards. As levels are completed, more complex Technique | Task | Technology | Team cards are automatically unlocked as a reward, thus providing richer, more varied design opportunities.
	Competence	When players are uncertain about card choice, they can call up system suggestions about the most appropriate cards to choose, thus permitting them to proceed with the design task. The system provides examples of good practice (virtual goods).
	Relatedness	Players work in groups and in this way gain personal experience of collaboration, which is one of the desired outcomes of their design activity.
Experience and appreciate collaboration among peers by co-designing collaborative activities for students	Autonomy	Assuming roles: each member of the group is assigned the role of "expert" in one or more card suits (Technique | Task | Technology | Team), making each member essential for carrying out the proposed design task.
	Competence	The system randomly launches quests, i.e. random events in which intra-team interaction is necessary to solve the posed "design problem".
	Relatedness	Group work continuously fosters meaningful dialogue and sharing among team members.
Start to integrate the 4Ts model into daily design practice	Autonomy	At the beginning of the game, each group receives a 'challenge/mission' to tackle that is set in the context of a realistic simulated situation. Tackling the design problem creates shared purpose. Challenges/missions are authentic and gradually become closer to players' actual daily situations, so that in the end teachers can define or choose their own problems.
	Competence	Manipulating variables: manipulating and playing with the tangible 4Ts cards allows teachers to develop their competence in solving design problems.
	Relatedness	The whole game is based on team effort.

which: “people may feel that they are being manipulated; little or no transfer is likely to take place if the learner is only motivated by the reward at the end; the risk that when the reward vanishes, so does the behavior, etc.”. [33] also suggests that focusing strongly on extrinsic motivation may even undermine intrinsic motivation.
As a consequence, it was agreed that, generally speaking, the game should not be based on common reward strategies such as leader boards and points and that competition should not play a key role in the game, lest this generate counterproductive effects.

Table 1 shows the Transversal Objectives identified in Step 1 and for each one lists the proposed game mechanics. These are suggested on top of the STD elements that, according to [18], support motivation.

As one may see from Table 1, some of the proposed mechanics originated the prototype 4Ts environment and have been retained in the new version. For example, team work was already an essential component of the environment and has been retained to support Relatedness and thus intrinsic motivation. Similarly, manipulating variables presented in a tangible form was an intrinsic part of the prototype 4Ts environment, and remains vital for supporting the Competence component of motivation.
Other elements such as structuring the game in levels and content unlocking are very common characteristics of games and are well suited to 4Ts as they help reduce cognitive overload, at least initially.

4Ts game

Group Mission/Challenge

As a team of teachers at a primary school, you need to conceptualize a collaborative activity that helps your students break the ice and socialize in a class composed of 20 five-year-old children with different backgrounds (11 Italian, 5 from Ecuadorian, 1 French, 2 Chinese and 1 Egyptian. The children of Ecuadorian background are all second generation immigrants who speak Italian and Spanish; the Chinese child speaks only Chinese, while the rest of the students with a foreign background speak and understand Italian reasonably well, but need to improve a lot.

Your aim is to design activities that break down the students’ tendency to talk and play almost exclusively with children who have the same background.

Fig 5 – Example of a hypothetical mission card in the 4Ts game

Other mechanics proposed for the gamified version of 4Ts are less common, but are already documented in the literature. For example, centering the game on design "challenges/missions" (see possible example in fig. 5) and having teachers assume roles are two mechanics suggested by [21] for allowing players to acquire and perceive Autonomy. These are well suited to our context, where we want teachers to solve design problems.
Lastly, by launching quests and offering virtual goods (new content) or suggestions, the 4Ts game features mechanics that support Competence.

Step 3 – Measurement and Evaluation
The last phase of the 4Ts gamification process regards definition of the indicators to be used for evaluating whether the objectives (as specified in Phase 1) have been met. In our case, this was done once again by the GD, who, via direct interaction with the 4TT, defined indicators for each of the previously identified mechanics. An example is given below in Table 2.

Table 2– Example of evaluation metrics associated to a Transversal Objective in the 4Ts game

Transversal Objective	**Metrics for evaluation**	
	Indicator	**Game Mechanic**
Learn how to design pedagogically informed collaborative activities based on the 4Ts model	Number of designs created per team	Designs
	Levels accomplished per team	Levels
	Number of virtual goods gained by each team	Virtual goods (suggestions, best practices, etc.)
…	…	…

6 Discussion

A beta version of the newly gamified 4Ts will be extensively tested in a teacher training event due to be held in Italy in Autumn 2016. The outcome of this experience will provide indications for evaluating the effectiveness of the game and for testing our assumption that, when applied to teacher professional development, gamification can be an effective means to support innovation adoption. These aspects will be the subject of later analysis. The aim of this paper is to discuss the gamification of the 4Ts environment and the methodology adopted for doing so, examining its suitability for teacher training and, more generally, the educational context.

Applying gamification to teacher training with the aim of fostering uptake of innovation in daily practice is a new undertaking. The current scarcity of experiences in this field might depend on a number of factors. The debate about the pros of gamifying learning processes is still open and somewhat controversial [34]; most teachers are still quite skeptical about adopting it in 'serious' contexts. As a target

population, teachers tend to be fairly reluctant innovators [35] and so proposing training actions that differ sharply from traditional formats may be risky.

Furthermore, educational organizations like schools and universities are intrinsically different from businesses, which are largely driven by competitive approaches and market-oriented logics. These factors match extremely well with typical gamification mechanics like leader boards, points and badges, and as a result such elements are usually well accepted in the gamified workplace. By contrast, there is a risk that in schools and universities such extrinsic motivators may be counterproductive. This, at least, is true in European countries; elsewhere, in more competition-oriented educational systems, things might work differently. So choosing the 'right' game mechanics is probably not only a matter of sector, but also a matter of culture of the country and dominant values and ethics.

In this perspective, the proposed gamification methodology has played an essential role in the described process, as it helped to clarify the characteristics of the intended users and prevented us from choosing unsuitable game mechanics for our target. Following a systematic and participative approach to gamification layer design, featuring input from focus groups of prospective users, oriented the 4Ts Group towards strategies that are in line with the culture and the sector at hand. The game mechanics we have chosen provide gradual and fading scaffolding and use problem solving approaches, factors that resonate with established training and educational practices in our country.

One limitation of the methodology that should be mentioned is that, even if it proved to be transferrable to our context, its roots in KM contexts caused some initial difficulties, at least as far as terminology is concerned. For example, at the beginning it was hard for the 4Ts Group to grasp the notions of "Business objective" and "Transversal objective" in light of our context. The term "Business objectives" was subsequently interpreted as the principal learning design goals, while the transversal objectives were intended as the main learning objectives, from the point of view of the teacher-players. Given that sharing a common vocabulary is an essential part of a collaborative process, making the methodology's terminology less context-dependent would enhance its potential applicability to a range of contexts.

7 Conclusions and further work

The application of [31]'s generic methodology to the context of teacher training was a fruitful experience in two fundamental respects. Not only did it help the 4Ts team conceive some suitable gamification mechanics for the 4Ts environment, more importantly it helped in the process of distinguishing which gamification mechanics are likely work in the teacher training context considered, and which might even prove counterproductive to the achievement of the defined "transversal objectives" (e.g. competition among teachers or rewarding for speed in task completion over quality of interaction and output).

An essential ingredient in the gamification process was the combined expertise in gamification methodology (the GD) and in the 4Ts environment to be gamified (the 4TT). While there was initial variance in the terminology each used, the process of application of the methodology made reciprocal understanding possible to the point that one further step towards improving the methodology documentation will be that of producing examples of application in different fields.

Among the drawbacks of using a gamification methodology of this kind, however, we should mention the fact that its strict application may hinder creativity to some degree. This is because the identification of gamification mechanics tends to follow the rails of the method and thus channels attention on the most typically adopted mechanics, rather than giving the designers' creativity full rein to devise mechanics that are peculiar to the environment.

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