Serious game design in practice: lessons learned from a corpus of games developed in an academic context

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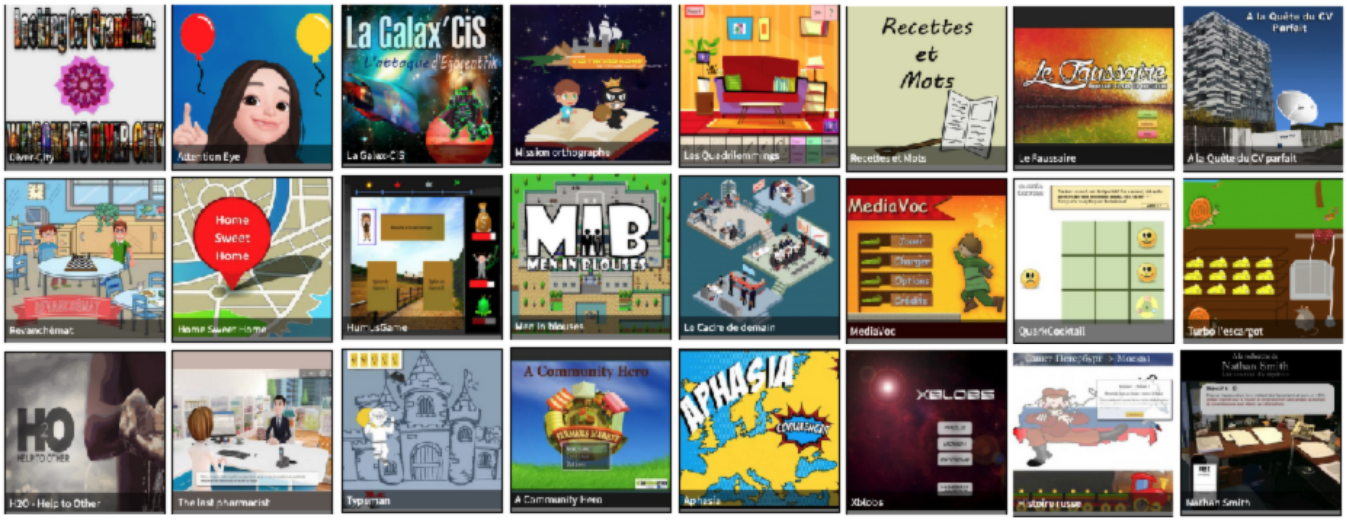

Figure 1: 24 learning games

ABSTRACT

This article consists of a post-analysis of twenty-four learning games, developed by master students within a dedicated course, over a period of twelve years. From this longitudinal qualitative analysis of serious game development, we are able to identify critical factors that make these games successful or not. We have grouped these factors into three axes: project organization, game mechanics and graphics. The variety of games produced in this academic context opens the way toward a more systematic analysis of this corpus, aiming at producing useful guidelines to design better serious games in an efficient manner.

CCS CONCEPTS

• **Applied computing** → **E-learning**; • **General and reference** → **Design**.

KEYWORDS

learning games, serious games, intrinsic integration

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1 CONTEXT

It is not that common to find a game development studio that released two dozens of serious games over a decade, concerning a large variety of topics, using various technologies and not limited to a given genre. This is however what could be achieved within an academic context, at the University of Geneva. As part of a master in Educational Technology (Master of Learning and Teaching Technologies[1]), the course entitled "Jeux vidéo pédagogiques" (pedagogical video games) aims at teaching instructional game design following a project-based approach. Since approximately 2009 (the course existed before but was more general and smoothly transitioned to a course on learning games), up to six games per year are produced. Each year, the games considered successful –according to the teaching team evaluation– are "released", that is, published on our lab's showcase game page [8]. This is not to say that this academic context is exemplary and produced numerous flawless

[1] https://maltt.unige.ch

serious games. But this context provides an interesting field of study on serious game design. This article aims at looking back at this corpus of serious games and drawing a few observations that may serve as more general guidelines in serious game design. In the rest of this section, we will describe more in detail the context of these games and the following sections will provide an analysis of the game design process according to three themes/lenses: the project organization, the game mechanics, and the graphics.

The course, offered during the master's first year lasts one entire academic year, for a total of 12 ECTS (European Credit Transfer System). It is provided in blended mode, combining face-to-face sessions and distance learning. It includes theoretical content, learning game analysis, design exercises, and finally a project: designing and fully implementing a serious game. As the course is at the Master level, the technical aspect is only one aspect: what is asked to the students is to conduct the project from A to Z, including providing a detailed need analysis regarding the project's context. With very few exceptions, games were developed in groups (from 2 to 4). The development phase itself lasts one month. Importantly, this context is far from being optimal, because 1) we are not in a game school where the whole curriculum is focused in one or two game projects; the presented games are produced within a single course, and 2) students are more leaning towards instructional design and education, often with very limited knowledge in games and development. These constraints are however interesting because they ask for ingenuity and simplicity, and require focusing on the core gameplay.

One of the key learning objectives in the course is the concept of learning content integration, also known as intrinsic integration [4, 5]. Designing basic serious games, such as quizzes with points, or game-like environment's where the player explores a world and must answer questions to move forward, etc. are "prohibited". Students must find a solution where the learning content is integrated with the game mechanic. This is an extremely hard problem —most serious games would fail regarding that requirement— and students do not always achieve that goal, despite the teacher's and tutor's guidance.

Our corpus contains twenty-four games, publicly accessible [8]. Three of them are not playable with current devices, due to the obsolescence of Flash (*Xblobs*, *Turbo l'escargot*, and *The Last Pharmacist*). All games are playable, with varying degrees of realization and polish. Most of them are prototypes that would need some improvement before being used in a real context. Sometimes the graphics need to be polished, or only a subpart of the content has been implemented. Nevertheless, these games are functional and the underlying concept can be clearly experienced. The discussion in this article is also based on 33 other games that were not selected for the showcase, often because they were not accomplished enough but also because they did not fit the web medium (e.g. tangible interface) or for confidential reasons (one game). Overall, over the years, a larger proportion of games were released because the quality generally increased as we learned how to better organize the course and drive the game design process. This is this gained experience that will be shared throughout this article.

2 PROJECT ORGANIZATION

A major characteristic of the course's organization in its current form is that each game project comes from a sponsor outside of the teaching unit. It may be a service at the same university (e.g. career service), an institution that has a special need (e.g. hospital, school) a company that develops serious games but wishes to explore other possibilities, an individual teacher, a non-profit organization, etc. It has not always been the case: previously projects originated from the students themselves. External sponsors have the advantage of providing a higher degree of authenticity, which not only makes learning more relevant but also motivates students. This is also motivating for the teaching team because the course may output useful products. Globally, we found that external sponsors improved the quality of the final games because real needs seemed to push students towards more achieved and successful games. At the same time, it also puts more pressure on the students' shoulders, which makes the course harder, the students reported. Also, the relationship between the sponsor and the students is not always easy to manage and is quite variable, depending on the sponsor's context. In some cases, the sponsor may be insufficiently available, and students have to put a lot of effort just to acquire critical information on the project. In other contexts, conversely, the sponsors would be willing to intervene more than expected, sometimes disturbing the project's progress and its very short timeline. As a result, we had to write out a "project charter", a short overarching document, common for all projects specifying the roles of each of the three following entities: the students, the sponsors, and the teaching team. This charter is given to both students and sponsors, at the start of the project. This has smoothed the progress of the projects, although this charter tends to be "forgotten" in the middle of the project. This authentic approach to project-based learning is now functioning well, but we would not recommend it for shorter projects because it takes time to establish an efficient working relationship between the students and the sponsors.

Another organizational issue is the building of the project team. In the beginning, the teams were built by the students themselves, mostly for affinity reasons. Sometimes labor was dispatched according to the game's parts: a student or a subgroup would develop the first part, while another student or sub-group would develop the other. This organization was in principle pedagogically desirable because each student would need to work on all facets of the game. However, it created difficulties during the project's development, and the games' quality was poor. Therefore we switched to heterogeneous project teams, build by the teaching team. According to their declared skills, students are grouped into teams that would gather all necessary skills. Ideally, each team comprises the following skills: education/psychology, project management, graphics, and development. Once the teams build, all projects are proposed and teams vote. This occasionally creates conflicts, within and between groups, but we manage to solve them quickly, sometimes by slightly changing group configuration. Such groups that comprise a blend of all skills manage to produce better games. In addition, their experience is closer to the real-life experience of professional game design.

As mentioned above, most students in the course are not developers, and within a team, the programming resources are quite

restricted. Requesting the development of a game in one month to a team with moderate technical skills is quite challenging. The solution lies in the adoption of authoring tools. Another organizational decision is the choice of which authoring tool for each project. We are regularly balanced between offering a single authoring tool for all projects (e.g. *Unity*) or letting each project team choose the most appropriate authoring tool. The first option allows better training for the authoring tool (even before the design phase) as well as better support, while the second option enables to adapt the tool to the needs of the project. The latter option has been chosen, offering more flexibility. We provide a list of suggested authoring tools, along with training material and assistance. For the last two years, these authoring tools include: *Construct 3*, *RPG Maker*, *Clickteam Fusion 2.5*, *Unity*. The choice of the authoring tool is critical. For example, the choice of Unity would not be encouraged if no trained developer is part of the team. *RPG* Maker, while strictly limiting the type of games that can be implemented, proved quite successful, in terms of the game's finish. *Clickteam Fusion 2.5* would be recommended for less proficient developers. Conversely, trained developers would also choose to develop the game directly in *HTML 5*, feeling less comfortable with the constraining logic of authoring tools. In the end, the choice depends on both the type of targeted game and the skills available within the team.

3 GAME MECHANICS

When facing a set of learning goals, designing a game that incorporates these goals at the core of the game is a real challenge for an instructional game designer. We do not put forward a specific methodology for game design, as we consider that as of today such methodologies remain invariably poor when it comes to the key issue: which mechanic would fit a given learning goal? We rather follow a classical iterative project development methodology [2], cycling around four steps —need analysis, design, implementation, evaluation— and rely on designers' creativity and multiple design iterations (including paper prototyping [3]) to come up with a suitable game mechanic. As a result, the developed games in the corpus propose a large spectrum of mechanics. We propose to analyze them via three design strategies that have been implicitly used during the design process of the games.

3.1 Contextualization

When conceiving a serious game, there is a natural and strong tendency to decompose the learning goal into a succession of small quests/questions that the player must solve/answer to move forward in the game. However, this approach makes games that resemble quizzes, which in general are neither good games nor good pedagogical products. Of course, one may object that they are good quiz games (e.g. Trivial Pursuit), but their good gameplay stems either from the scoring mechanic that surrounds the questions (including multi-player competition mechanics) or the fun of the questions themselves. Despite that willingness to surpass the quiz approach, often, the learning domain itself seems structured into a succession of questions: training the word/sound relation for people suffering from aphasia ("Aphasia" game in the corpus), enriching vocabulary for primary students ("MediaVoc" game in the corpus), etc. For those games, the basic quiz mechanic of asking questions and providing a score has been modified by linking the questions to the context, to the fantasy [5].

For example, the *Aphasia* game has been developed for speech therapists. It aims at helping people who have lost some speech abilities. Typically, speech therapists would use basic exercisers that consist in showing words and asking the user to choose the corresponding image. The game proposes the same kind of exercises but within a context. The game's story is presented as an investigation of a father looking for his son. In the first level, the father must pack his suitcase and to this end, the player needs to identify correct items based on the written word corresponding to the item. This contextualization transforms the exercise into more meaningful activity, both at the level of the fictional world (the room) as a packing activity and at the level of the narrative (preparing a trip to help the son). interestingly, further levels in the game did not manage to contextualize the exercise with the same clarity.

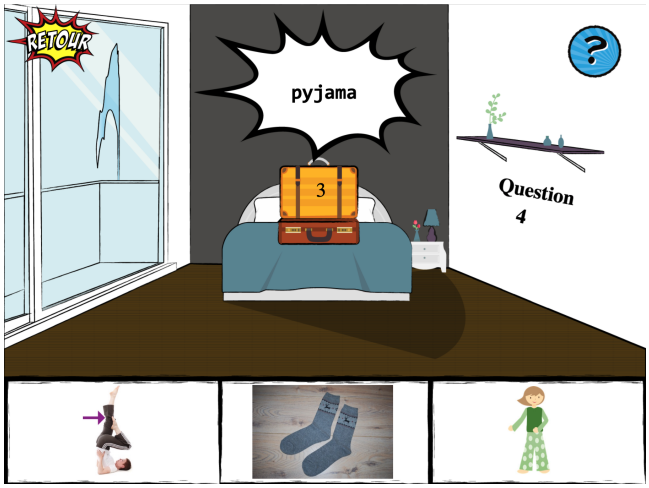

Figure 2: Screenshot of the *Aphasia* game

Another similar example is the game "Des recettes et des mots". Dedicated to teaching some french vocabulary to young children arriving in a french speaking country, the game contextualized the word learning exercise into a cooking recipe. Words are not just organized into a word list but are ingredients and kitchen equipment that need to be selected to make the recipe.

The game *Men in Blouse* ("blouse" being the white coat of medical staff) uses this principle in a more sophisticated way. The game aims at recalling the main hygienic principles for medical staff. These principles have been declined into a series of simple situations that violate these principles, that the learner must detect as inappropriate. These situations are then inserted into the following fantastic and humorous story, inspired by the movie Men in Black: some aliens have invaded the world and are disguised as medical staff, but they ignore hygienic principles and would behave inappropriately. The mission of the player is to uncover them. One cannot argue that in this game, the main game mechanic of navigation incorporates the learning goals, but it serves as a context to make the learning situated in a relevant environment (a hospital).

Interestingly, the story in this case does not aim at providing any authenticity to the experience: the game is not simulating the work condition and situation of medical staff. Yet it plays a central role in contextualization and fun.

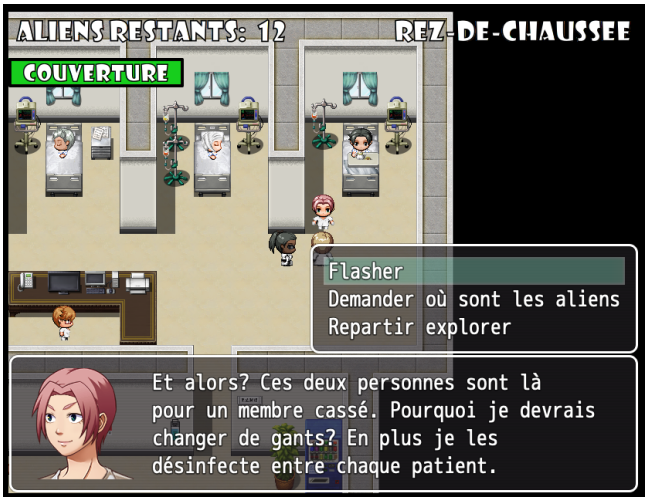

Figure 3: Screenshot of the *Men In Blouse game*

The last example for this section, the game called *Typeman*, also has a story that provides a context for the player's task. But in this case, the player's task is more artificially connected to the story. This game aims at teaching typewriting to one specific child with multiple physical disabilities. It is a simple platform game where the player must quickly type the letter appearing on the screen to avoid traps when running. The game is contextualized within a story tailored to the player: the hero, a knight, collects letters that escaped from a spelled dictionary. This story, as well as the fact that the player character is running, has little to do with the learning content and mostly serves as an extrinsic motivational context. Is it problematic, given what we wrote above regarding games designed as quizzes? Not really, because we are dealing with visual motor skill learning for which repetition is the main approach for learning.

3.2 Enriched mechanics

In other cases in our corpus, still dealing with a learning content that would be (too) easily covered with a quiz-like approach, instead of just adding some context to the quests/questions, the mere question answering mechanic has been extended to a more sophisticated one. The term "extended" is essential here: it does not consist in adding another mechanics next to the question answering one, as is often the case in poorly integrated games (for example the often cited *Math blaster*). The question-answering mechanic does not exist as such. We will provide two examples of this approach.

The first example is a game that teaches the decomposition of elementary particles into quarks. The game does not pretend to teach complex notions of quantum physics, just how different combinations of three quarks create different particles. The game uses a 3 per 3 grid where the player must place the quarks that arrive sequentially on the screen, in a limited time, after which the quark is randomly placed. When three quarks are on the same line and constitute a known particle, they merge into that particle that stays on the grid. For each level, the game provides a goal, such as "create two neutrons but no proton", and the player must carefully place the quark on the grid in order to manage this goal before the grid is full. The player can consult a help screen that indicates which quarks make which particle. The game is challenging and manages to engage the player to continue through successive levels. In this game, the player must know which quark makes which particle (learning content) but this is not directly asked by the game. Instead, the interesting part of the gameplay is to anticipate which quark may come and which particles may be built with current and upcoming quarks. Therefore, part of the game mechanic, the spatial and temporal reasoning around the grid has nothing to do with the learning content. Yet the game engages the player in an activity in which she has to repeatedly assemble quarks into particles. The designers' goal is that after a while, the player does not need to read the help screen anymore, which would demonstrate that she has acquired the knowledge.

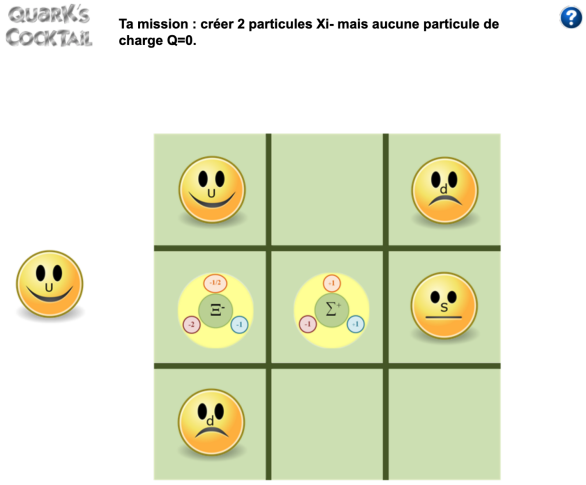

Figure 4: Screenshot of the *QuarkCoktail* game. The mission is to create two Xi particles but no particle of null charge.

The second example concerns a game that teaches important dates in Russian history. This time, the game mechanic has not been fully created from scratch but borrowed from an existing card game called Timeline[2]. In the implemented version, the player is given a number of cards representing historic events in Russia. One card is already placed as a wagon in a train (a metaphor of a train is also used, as part of a global story, that will not be detailed here and has not been fully developed in the game). The player must place a given card at the left or the right of the card already in place, depending if she thinks that the event happened before or after that card. When the card is correctly placed, it remains there and the date of the event is given, as well as a text commenting on the event. Then the player can try to place another card. Progressively, more and more cards are placed, and the chronological placement

[2]https://uk.trictrac.net/boardgame/timeline-0

of the remaining cards gets harder because the player must choose between dates closer together. This mechanic is interesting because it does not ask for the dates of the events, only to place an event between two dated events.

3.3 Systemic mechanics

Finally, some games make use of more complex mechanics, in the sense that when a player chooses an action, it changes internal variables in the system that may influence future game states. The game is not divided into small almost independent quests, but the quest is global and influenced by actions taken over the whole experience, consistently with the definition of games as systems [9].

A typical case is *HumusGame* that aims at explaining the nature of soils (made of humus) and how it is influenced by various external entrants such as fertilizers. In this game, the dynamics of the soil are simulated: the level of humus, the rate of minerals, the pollution of the groundwater, and the food produced by planted culture are all calculated dynamically, according to time, the presence, and types of fertilizers. This simulation is embedded into a game's goal: being able to feed all the villagers around. This game is a typical case of a simulation learning game where the content is straightforwardly inserted into the mechanics.

Figure 5: Screenshot of the *Xblobs* game

Such simulation games are not the only type of serious games that exploit the systemic nature of game mechanics. In our corpus, the game *Xblobs* teaches the resolution of linear equations in mathematics. For that purpose, it represents the equation as two spaces, where numbers are represented as red (positive) or blue (negative) units, and variables ("X" in the equation) as blobs. The player can add units or blobs to both sides of the equation, which changes the corresponding visual representation as units and blobs. With such mechanics, she can solve the equation: solving the equations is equivalent to isolating one blob on one side of the representation. With proper scaffolding, the game can teach students how to solve such linear equations, or at least provide an alternative way to teach this complex notion.

Finally, a third game in the corpus is worth mentioning, as it is a typical narrative game. *Home sweet home* aims at heightening awareness of the difficulties of foreigners when they arrive in the country. It is dedicated to social workers. It features a foreign woman arriving in the county, looking for a job, a place to rent, etc. It is a typical choice-based game, but it also includes a mechanic of three variables — represented as bars — that vary according to the player's choice and then influence the further possibilities (resources, mood, and integration in the country). This mechanic largely enriches the choice-based narrative, with multiple and longer-term causality between choices.

4 GRAPHICS

As explained above, the development team has variable and usually limited skills in graphic design, as is often the case in academic labs involved in video games. This shortage in graphic skills has guided the game development towards a few tricks and solutions to overcome this limitation and deliver aesthetically good or acceptable games:

- Use ready-made assets. If some authoring tools include the possibility to create some graphical assets, in the general case, they are based on standard formats so that game designers can import them. There exist large data banks of 2D and 3D graphical elements, many of them being free. The students are offered a list of relevant open source websites providing such free content. The difficulty at that level is to find graphical universes that depart from the typical games' environments (fantasy, science fiction, etc.), as it is often needed for serious games.
- Use an authoring tool that embeds the graphics. While most authoring tools are focused on development and prefer leaving the graphical content outside of the tool, some of them include a large variety of graphical material that can be straightaway added into the game. This is the case for *RPG Maker MV*, used in three games in our corpus (*A Community Hero*, *Men In Blouse*, *La Galax'CIS*).
- Use graphical rendering effects. Graphical effects on images, such as cartoonization or posterization provide a graphical identity to the game and help align all images by hiding defaults and singularities. In *Home Sweet Home*, for example, the team took pictures of themselves and friends in everyday situations and applied a filter to all images.
- Use specialized graphic design tools. General graphic design tools allow users to create any graphic but require high artistic and technical skills. More specialized tools enable to easily create a very focused type of graphics. In our corpus, for example, the application called "FacedApp" was used to make characters older in *Diver-City*. In a game not yet in the corpus, the *NanDeck* software enabled the creation of high-quality game cards. Much other software may be used for specific needs, including AI-based image generators that are becoming widely accessible nowadays.

These four solutions are not exclusive at all and were usually combined within a single game. They are also not incompatible with the presence of a graphically skilled team member. Choosing the

right image bank, and the right imaging tools also requires graphical skills to some extent. In the end, we observed that the graphic quality was critical in the final success of the game. Many games were not selected for the web showcase because the graphics were unfinished or too poor. Generally speaking, games did benefit from members who had graphic skills (*H2O*, *Typeman,* Xblobs), but other games were aesthetically satisfying as well, without those skills (*Men in blouse*, *Les Quadrilemmings*).

5 CONCLUDING REMARKS

We have analyzed the outcome of twenty-four successful serious game design projects, as well as other games produced in the same context but not published in the lab's showcase, for a better understanding of the critical factors that make these games successful or not. For all these projects, we targeted high-quality serious games, not necessarily in terms of visual finish and gameplay but rather in terms of the concept's originality and relevance. We do not provide "recipes" to our student design teams, considering that serious game design is a craft, not an industrial activity. There exist too many directories of serious games of poor quality, mostly exercisers, in fact, so we pull the projects towards more advanced products. As a result, each game is a unique piece.

From the observation of these games and the knowledge of the design process that accompanied the development of each game, we identified and discussed three critical dimensions that highly influence the success of the game: organization, game mechanic design, and graphics.

Globally, games in the corpus are quite different from each other, confirming the above-mentioned uniqueness. Among the produced games, we have:

- Games that straightaway reproduce an existing game mechanic because it suits the instructional design goal of the project (*Histoire russe*). Role
- Games that borrow well-known mechanics but adapt them to the learning goals, such as narrative choice-based games (*Home Sweet Home*, *The Last Pharmacist*), Role-playing games (*H2O*), platform games (*MediaVoc*, *TypeMan*), simulations (*HumusGame*), adventure games (*Aphasia*), Lemmings-like game (*Les Quadrilemmings*), etc.
- Games with fully original mechanics (*Xblobs*, *Le faussaire*, *Nathan Smith*, *QuarkCoktail*, *Diver-City*).

The games in the latter category are not necessarily better — with a focus on the mechanics, they often have lacked time and resources to tune other aspects — but they represent an important direction for serious games, that should be encouraged.

From these twenty-four examples, can we draw a more general methodology of innovative serious game design? There exists today a variety of game design methodologies [1, 6, 7], covering many aspects, including organizational ones, but when it comes to the core of the game, its mechanic and how it integrates intrinsically the learning content, these methodologies either are silent or they impose a certain type of approach, for example, simulation-based [7]. Finally, one relies on the creativity of the designers and their ability to work together efficiently. We believe that our corpus and its analysis may provide guidance in this core design issue. Certainly not as a systematic method —again, we believe in the fundamental artisanal nature of the process— but at least as a set of tips, insights, and good practices to foster creative solutions. For that purpose, our next step is to analyze not only the games but also the game design documents, including when the games were at the stage of brainstorming, to better understand how good ideas were finally produced, selected, and materialized.

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