

Towards a Revised LM-GM Framework for Classroom Analysis: A Systematic Literature Review

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Abstract: The Learning Mechanics – Game Mechanics (LM-GM) framework has become a foundational tool for the design and analysis of serious games (SGs). However, its application within the specific context of adolescent classrooms (learners aged 12 to 16) remains underexplored. This paper conducts a systematic literature review on LM-GM and its different applications and extensions to examine their current state. This review aims to assess whether the LM-GM framework can be adapted for an analysis of game-based learning in adolescents' classrooms. The findings suggest that the LM-GM framework is good enough to function as a baseline across stakeholders but can be adapted with adjacent principles, like self-determination theory.

Keywords: Serious games, LM-GM framework, Adolescent education, Game-based learning, Systematic literature review

1. Introduction

The Learning Mechanics – Game Mechanics (LM-GM) framework, since it was introduced by Arnab et al. (2015) represents an important and widely adopted contribution to the analysis and design for serious games (SGs). Structured approaches to mapping learning objectives and game mechanics have been explored for decades, starting intrinsic motivation (Malone et al., 1987) up to prescriptive guidelines for designing game-based learning environments (Garris et al., 2002). The LM-GM framework formalized this process in a systematic and transferable way.

The LM-GM framework functions based on the explicit linking of Learning Mechanics (LM) (pedagogical mechanisms of learning through reading, practicing, constructing, reflecting and collaboration) with Game Mechanics (GM) (rules-driven features of the game motivating players behavior, like challenges, rewards, role-playing, exploring and competing). The mappings are represented visually as a grid or matrix, allowing designers and researchers to assess how particular elements of games contribute to learning outcomes. It should be noted that the LM-GM framework is flexible enough for not having any fixed taxonomy.

Since its introduction, the LM-GM framework has been adapted to many educational domains, from engineering education (Callaghan et al., 2017) to health behavior change (Iskandar et al., 2024). Researchers extended the framework in multiple directions, connecting the framework to motivational theories such as Self-Determination Theory (SDT) (Proulx et al., 2017), and incorporating players / learners' profiles (Monterrat et al., 2017).

In classroom settings with learners aged 12 to 16, the framework needs to be extended further because it does not model adolescent differences or classroom constraints. Recent literature suggests that mappings can support adolescent autonomy, fit teacher-led guidance, and adapt to meaningful differences among learners (Arnab et al., 2017). Therefore, it seems necessary to feel ownership while being focused on the task and receiving necessary guidance from teachers (Kim et al., 2025).

2. The LM-GM framework as a Starting Point

2.1 The LM-GM Framework in Relation to Other Models

It is worth to first clarifying the inner workings of the LM-GM framework before looking at other frameworks. According to Arnab et al. (2015), the proposed model uses a table in which rows denote the LMs borrowed from educational theories such as Bloom's taxonomy, while columns represent Game Mechanics categorized by their functional role in gameplay (e.g., progression, feedback, collaboration, role embodiment). A cell in the matrix is marked when a specific GM can be said to facilitate the use of a certain LM, thereby providing an explicit way of linking the two. This approach allows not only the analysis of the already existing game but also the identification of the areas where there are present mechanics in the game that do not have pedagogical value and vice versa.

The LM-GM framework is not the only model available for SG analysis and design. A relevant framework is the Activity Theory-Based Model of Serious Games (ATMSG) (Carvalho et al., 2015). The ATMSG framework provides a richer mapping of GM and LM: it poses a more general system by differentiating gaming activities,

learning activities and instructional activities. For a classroom-based study, the advantage of the activity theory approach is its focus on teacher orchestration. The ATMSG framework is also more detailed, containing an extensive taxonomy of actions, instruments and objectives that can describe a classroom SG ecosystem more fully than the LM-GM framework. In the evaluation reported in Carvalho et al. (2015), most participants considered the ATMSG more complete than LM-GM, but harder to use. Since their introduction, the LM-GM framework's publication has approximately 2 times more citations than the ATMSG framework's application.¹ This suggests that the LM-GM framework has broader adoption and usage within the academic community for SG analysis and design.

The Learning Objective – Game Objective (LO-GO) mapping framework (Clarke, 2016) is a narrower model than the LM-GM framework that translates learning objectives to game objectives but is still a direct lineage of the LM-GM framework. The Constructive Alignment Extension (Kalmpourtzis, 2020) is a recent model built beyond the LM-GM framework and is a strong alternative for assessment in classrooms.

For the present project, the LM-GM framework offers a clearer starting structure because it has the strongest literature based on later extensions and is flexible enough to absorb surrounding theories.

2.2 The LM-GM Framework with the Perspective of Adolescent Classrooms

The learning motivation of 12-to-16-year students largely depends on peers, confidence, sociotechnical profile (Troeger et al., 2022) and balancing freedom and directionality (Taub et al. 2020). This means that the significance of SDT is higher in relation to this population than was previously discussed. Therefore, it seems necessary to design SG in a way to allow learners to feel ownership while being focused on the task and receiving necessary guidance from teachers (Kim et al., 2025). While in higher education research, LM-GM is often perceived as a tool for the mapping of mechanics (Arnab et al., 2017), it is important to remember that the framework should survive in an instructional environment in which teachers actively shape how learning is experienced.

3. State of the Art of the LM-GM Framework and its Extensions from the Perspective of Adolescent Classrooms

To provide an overview of current and upcoming trends when it comes to the adaptation of the LM-GM framework, we have decided to conduct a systematic literature review of papers that apply this framework rigidly and those that apply it with extensions and flexibility, both inside and outside adolescent classrooms. This will allow us to gain an understanding of the effectiveness of the different approaches and to formulate best practice strategies for use with students in the classroom setting.

3.1 Methodology

To establish a scientifically pertinent review, we chose to use the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement (Page et al., 2020).

3.1.1 Search criteria

We conducted our search by combining the terms “learning mechanics” and “game mechanics.” In the search for articles related to “serious games,” we looked for papers that address “LM-GM” while searching through ERIC and JSTOR databases. A substantial number of papers came up: close to 800 papers. While looking at the papers' title, we added filters that included years (2015-2026) and subject areas (Education Sciences and Computer Sciences in JSTOR). We also used the help of an artificial intelligence service called Scispace² for our research process. To find more articles in our literature review agent, the following prompt was used: *“Provide a combined list of papers that address the following question: What are the applications and extension of the Learning Mechanics Game Mechanics framework by Arnab et al. for serious game design?”*, which returned 55 papers. We also looked for papers related to player profiles and papers related to SDT in connection with an extension of the LM-GM framework. We carried out two other searches in the same databases with the following keywords: “player profiles” or “player profiling” and “adaptation” and “learning mechanics” or “game mechanics,” as well as “self-determination theory” or “STD” from the viewpoint of “serious games” and “learner agency.” The following prompts were used in the Scispace agent: *“Provide a combined list of papers*

¹Gathered on April 28th, 2026, on ResearchGate Citations

²SciSpace is an artificial intelligence developed by PubGenius Inc (USA): <https://scispace.com/>

that address the following question: *What are the approaches for player profiling and personalization in adaptive serious games with learning mechanics?*” and *“Provide a combined list of papers that address the following question: How does self-determination theory explain learner agency and motivation in serious games and game-based learning environments?”* Three hundred and fifty-three papers were retrieved from this stage, and 9 additional papers were added through serendipity sources.

3.1.2 Inclusion and exclusion criteria

The first step was to exclude duplicates, papers written in other languages than English and French, or off-topic papers. Off-topic articles were identified from their titles and abstracts when they deal with general game design, XR environment, entertainment-only games, non-digital or they do not deal with serious games (n=124). Papers that do not contribute to the LM-GM framework were excluded in the first search scope. For other scopes, papers that do not consider players’ profile or STD were eliminated (n=89). Next, studies with SGs with adaptive elements where the game itself or its content can be adjusted dynamically or with the help of artificial intelligence, have been excluded, since the search mistakenly took it for the concept of adapting the framework. One more filter was introduced for adult learning environments considered too far from the classroom experience, such as online learning (n=26). Yet another filter has been included for papers addressing SDT or player profiles without an adaptation of the LM-GM framework (n = 41).

At the eligibility assessment stage, the papers were retained when they met one or more of the following conditions: (1) The LM-GM framework was central, (2) the paper addresses adolescent learners, (3) the paper contributes to bridging SDT and player profiles to LM-GM.

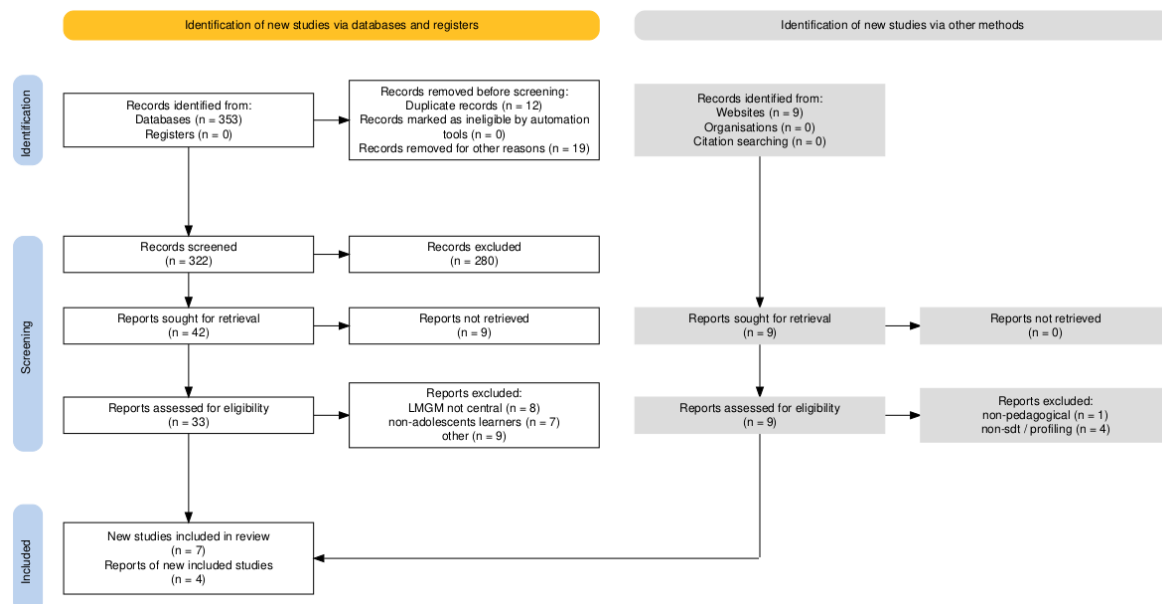


Figure 1: PRISMA Flow Diagram³

4. Discussion

4.1 Notable Extensions and Applications of the LM-GM Framework

The reviewed literature reveals four particularly significant applications and extensions of the LM-GM framework that map the trajectory of the field.

Callaghan et al. (2017) demonstrated the practical application of the LM-GM framework in higher engineering education, specifically in the context of a game called “Engineer the Future”. This study is most comprehensively documented LM-GM among those described in the reviewed literature. The authors employed the LM-GM model not only as an instrument for designing the game, where the GMs were mapped on the LMs taken from engineering competence frameworks, but also as an instrument for evaluating pre-game and post-game learning outcomes. In particular, the researchers observed that the explicit mapping of

³PRISMA Flow Diagram (Hadaway et al, 2022)

LMs and GMs positively impacted the engagement of students with learning objectives, though the authors noted that framework required domain-specific adaptation to accommodate the problem-solving demands of engineering tasks. Despite not being applied to an adolescent classroom, this application is the most documented application that includes an analysis of learning outcomes, the design of game mechanics, scoring mechanics, and performance tracing.

Jaccard et al. (2021) have developed the co.LAB framework, incorporating the LM-GM framework as one component within a larger ecosystem that consists of building blocks organized into five categories: context/objectives, mechanics, game design, learning design and assessment. It focuses on a collaborative, adaptive, and systematic approach, making it possible to customize the framework for various serious games. What distinguishes the co.LAB from a simple LM-GM extension is its focus on project management and stakeholder communication, as the framework is aimed at enabling collaboration between multidisciplinary teams (educators, game designers, developers) for the creation of SGs. However, as far as adolescent classroom settings are concerned, the co.LAB framework seems to be useful from the organizational perspective but does not address learner-level differences or motivational considerations specific to adolescents.

The Reportable Serious Game Mechanics (SMGX) developed by Shearer (2024) is a significant extension of LM-GM. The SMGX develops a human-readable and machine-processable framework by providing an ontological structure that represents game events as statements. Since the approach of the framework is new, it has not seen many practical implementations. Its potential significance for classroom settings lies in its compatibility with AI-based personalization systems due to the structured format of generated event logs which can be used to adapt the difficulty level or content based on behavior of each learner.

Iskandar et al. (2024) provide the review's most directly relevant designed for learners aged 13 to 15. The study compares two versions of a game: one designed without the LM-GM framework and one improved using its principles. The results showed that the latter variant yielded better engagement outcomes. Notably, the authors identified genre, flow, and felt-competence as the most effective LM-GM elements when used in the game for adolescents. Thus, in developing adolescent SGs, the effective and motivational elements of the game such as immersion and perceived competence could play a similarly significant role in the alignment between mechanics and learning objectives.

4.2 The LM-GM Framework and Self-determination Theory

Since its introduction, the LM-GM framework has been augmented and extended by researchers looking to adapt it to new contexts and to integrate it with complementary theories and technologies. The LM-GM-SDT developed by Proulx et al. (2015, 2017) shifts the focus from the structural alignment of mechanics to motivational quality of individual game mechanics. Specifically, it asks whether a given GM supports the three fundamental psychological needs according to SDT: autonomy (voluntary control of behavior), competence (mastery and effectiveness), and relatedness (connection to other people). A GM that supports all three needs is expected to foster intrinsic motivation, whereas one that satisfies none, or only competences under the threat of external pressure alone, may lead to externally motivated activity.

This distinction becomes particularly significant in the context of adolescents' classrooms. Studies on adolescent motivation consistently show that 12-to-16-year-old learners are especially sensitive to peer dynamics (relatedness) comparison of their performance with their peers (competence), and the degree of choice they are afforded (autonomy) (Troeger et al., 2022; Kim et al., 2025). An LM-GM mapping that does not address the motivational aspects of the mechanics and only considers whether they align with the learning objective will likely produce games that are pedagogically coherent but motivationally inert for this population.

Lobo (2030) further developed this line of reasoning by exploring the potential application of the LM-GM scheme in terms of not only determining the level of engagement but also assessing the type of motivation underlying it. The analysis of a collaborative learning tool found that certain game mechanics (e.g., visible leaderboards and competitive scoring) consistently corresponded to the externally regulated level of engagement and did not correlate with intrinsic motivation at all. This finding is especially important for adolescent classroom design since visible participation may indicate compliance behavior and not intrinsic motivation.

Together, these studies provide convincing evidence for approaching the use of SDT extension as something which is almost compulsory within any implementation of the LM-GM framework within the adolescent

classroom setting. The use of the clarity of structure provided by the LM-GM model along with the motivational focus provided by the SDT theory addresses complementary gaps.

4.3 The LM-GM Framework and Adolescent Profiling

One of the most significant gaps in the reviewed literature is the absence of a direct LM-GM extension that includes learner profiling. This gap likely reflects the difficulty of introducing the element of an individual level concept into a system meant for the population level.

The adjacent literature on player profiling and adaptive gamification, which does not have direct relevance to the study of LM-GM, provides some useful insights. Monterrat et al. (2025) developed a player model for adaptive gamification in learning environments, identifying six player-type dimensions (Explorer, Achiever, Socializer, Competitor, Distractor, and Free Spirit), thereby showing that different profiles of learners react differently to gamification features. Their subsequent work (Monterrat et al., 2017) used adaptive gamification in a real learning environment, confirming empirically the potential of personalized game features based on profiles' motivational outcomes. Though the effects were heterogeneous across profile dimensions.

Lavoué (2019) observed that adapting game features based on player profiles did not clearly lead to improvement of enjoyment, suggesting that the relationship between preference and performance did not reliably improve performance. Halifay (2020) similarly observed that profile-based adaptation did not reliably improve performance, and the design introduced by profiling may not always pay off pedagogically. These findings do not dismiss the value of learner profiling outright, but they do caution against treating it as a straightforward solution.

The sociotechnical profile of a learner (Troeger, 2022) is not included in this review, but it can be relevant to look upon to complete the review on profiling. The sociotechnical profile considers not just the preferences of the learner in relation to gameplay, but the entire interaction they have with digital media as well as their social role in the class environment. Incorporating sociotechnical profiling into an extended LM-GM framework could provide a richer basis.

5. Conclusion

The LM-GM framework remains a strong framework for aligning learning and gameplay but does not yet offer a mature model for adolescent classrooms. What the current literature gives is a solid basis to build upon. First, there is the mapping language provided by LM-GM itself. Then, SDT explains why some aspects of the mechanics support agency and others do not. Next, the literature is clear on the central importance of the LM-GM framework and new studies have proposed some adaptations which could be relevant for the classroom setting of adolescents. Game features that vary across learner profiles are not to be relied upon alone.

For learners aged 12 to 16, the LM-GM framework is best treated as incomplete but extendable. A research project that would put LM-GM to use in the design or evaluation of SGs in classrooms by adding pertinent extensions and adaptations would address a gap in the literature.

Ethics Declaration: Ethical clearance was not required for the present study.

AI Declaration: DeepL translator, an Artificial intelligence tool developed by DeepL SE a Cologne-based company, used to support translations from French to English.

SciSpace, an Artificial intelligence tool developed by PubGenius Inc., a company based in Milpitas, California, USA. SciSpace was used as a search engine to support the literature search. All search terms are listed in the corresponding chapter.

All results were reviewed and validated by the author.

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