

Inventory of Digital Game-based Learning Practices for Chemistry Education: A Systematic Review

Maxime Hansen and Vincent Natalis

University of Liège, Belgium

M.Hansen@uliege.be

Vincent.Natalis@uliege.be

Abstract: In the field of chemistry education research, a large body of literature explores the use of game-based approaches to teach scientific concepts. However, this corpus primarily focuses on the use of educational games in classroom settings, sometimes without investigating their quality or reporting variables measured among students (Hu *et al.*, 2022; Xu *et al.*, 2025). Several synthesis works have offered broader overviews of the use of games in chemistry education (Byusa, Kampire and Mwesigye, 2022; Hu *et al.*, 2022; da Silva *et al.*, 2025; Xu *et al.*, 2025; Elmali, Freund and Tiemann, 2026). However, as those papers used a general perspective on games in chemistry education, more specific game types, media types or chemistry learning concepts have not been investigated. Inconsistencies in methodology are highlighted, such as confusion between game-based learning and gamification approaches (Becker, 2021; da Silva *et al.*, 2025; Elmali, Freund and Tiemann, 2026), leading to inclusion of gamification studies in game-based learning focused papers. In addition, methodological frameworks for systematic reviews, such as the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA), are only described in three of those works. This led to the hypothesis that this field of research could benefit from a more clearly defined categorisation of game-based approaches (Elmali, Freund and Tiemann, 2026) and from the study of the mechanisms behind learning with games (Hu *et al.*, 2022). Therefore, a systematic review (with or without meta-analysis) focusing on digital game-based learning is considered. Using the PRISMA framework, we explored three databases (ERIC, SCOPUS, and EBSCO) and two journals (JCE and CERP). A total of 2242 records were retrieved for initial screening using titles and abstracts. As this is the current stage of this research, eligibility and analysis of the data will take place in the future.

Keywords: Chemistry, Systematic review, Game-based learning, Digital, STEM

1. Background

1.1 Game-based Approaches in Chemistry Education

Uses and effects of game-based approaches for teaching have been a documented topic among scholars and educational researchers (Mayer, 2014; Plass, Homer and Kinzer, 2015; Plass, Mayer and Homer, 2020). Researchers argue that games improve some characteristics of formal educational contexts: they allow the development of constructivist learning environments (e.g. Papadakis, 2018), they afford the opportunity to be in situations that are not possible in real life (Becker, 2017), and they increase learners' motivation (van Roy and Zaman, 2017). The field of chemistry education research also presents a significant body of literature on games in education. However, studies published in chemistry education journals are more focused on the development of games and classroom activities, rather than on the measurement of the effects of game mechanics on, e.g., students' motivation, performance or representations of chemistry concepts.

Several reviews have since offered broader overviews of the topic — e.g., Byusa, Kampire and Mwesigye (2022) and Hu *et al.* (2022) early on, and more recently da Silva *et al.* (2025), Xu *et al.* (2025), and Elmali, Freund and Tiemann (2026). Those articles examine different game-based approaches (Elmali, Freund and Tiemann, 2026) or use a bibliometric methodology to investigate games in chemistry education (da Silva *et al.*, 2025). Among those papers, only two meta-analyses (e.g., Hu *et al.* (2022) and Xu *et al.* (2025)) focus on investigating the effects of games on students' cognition, motivation or emotion.

However, inconsistencies in methodology are highlighted. Some review papers do not make the distinction between game-based learning (GBL) and gamification approaches. Even if those two terms are often confused in the literature (da Silva *et al.*, 2025; Elmali, Freund and Tiemann, 2026), they refer to different concepts (Becker, 2021). This confusion led to the inclusion of gamification studies in GBL reviews, weakening the overall conclusions of these works. Furthermore, as the time span covered by those reviews ranges from 10 to 100 years, comparison between papers is also made difficult.

As the existing reviews covered a wide variety of game-based approaches, including board games, escape rooms, digital games, and gamified activities, this limits the identification of design features and chemistry learning obstacles that are specific to a particular game or media type. In addition, the absence of a common methodological framework for synthesis review hindered the comparability of review findings. As the

exploration of refined categorisations and learning mechanisms is recommended in the literature (Hu *et al.*, 2022; da Silva *et al.*, 2025; Elmali, Freund and Tiemann, 2026), the characteristics, pedagogical uses, and learning outcomes therefore need to be examined using a narrower categorisation of games.

1.2 Research Questions and Present Study

The limitations identified above justify more precise and focused research on well-developed chemistry games (Hu *et al.*, 2022; Elmali, Freund and Tiemann, 2026). Consequently, this work is based on three main research questions:

RQ1: What are the available games and body of literature solely focused on Digital Game-Based Learning (DGBL) practices for chemistry education, from secondary through higher education?

RQ2: What are the characteristics (e.g., pedagogical scenario, play times, topics, etc.) of these DGBL practices in chemistry education?

RQ3: How do DGBL practices help to overcome learning obstacles in chemistry education?

The main objective of this research is to focus on a narrower media and game type. More specifically, this study considers a digital, game-based learning approach, as this view is less frequently encountered in the scientific literature. This study therefore conducts a systematic review of Digital Game-Based Learning (DGBL) practices to provide an overview of their use in chemistry education and to investigate their key characteristics such as game mechanics, pedagogical scenario, student level, play time, etc. Finally, investigation of their use as a tool to overcome learning obstacles will also be pursued, as this is not discussed in the literature. A meta-analysis component is also considered, depending on the quality of the extracted data.

A secondary objective of this systematic review is to develop a database of DGBL practices that can be used by chemistry educators, with the objective of describing key characteristics (e.g., price, availability, language, pedagogical scenario, etc.). Such a database, solely focused on chemistry, is partially found on the website “Learn With Dr Scott” (Beaver, 2026), but only with a short description of the game.

2. Method

2.1 Systematic Review Framework

The PRISMA framework and guidelines were adopted, as it is the reference framework used in other systematic reviews within the field of chemistry education research and provides a standardised methodology for reporting systematic reviews (Page *et al.*, 2021).

2.2 Identification Phase

Databases (ERIC, Scopus, and EBSCO) and specialised journals in chemistry education research (*Journal of Chemical Education* and *Chemistry Education Research and Practice*) were used to identify relevant articles. Snowball searching was also used as a complementary search method when new references were not extracted using all previous methods. Different research strings were tested and used depending on the databases or journals. The search strings included both “game-based learning” and “gamification”, as those terms are often confused in the literature (Becker, 2021; da Silva *et al.*, 2025). A distinction between these two concepts will take place in the eligibility phase. The search was not limited to peer-reviewed articles, as many games have been developed and published in the grey literature.

2.3 Screening Phase

A total of 2673 records were extracted and exported to the Zotero research tool. After elimination of duplicates and articles excluded by the software, 2242 records were kept for an initial screening step. Articles were retained if they explicitly mentioned a game approach and chemistry education in their title or abstract. As this is the current stage of the research, the phase of the review is being conducted solely by the author.

2.4 Eligibility and Analysis Phases

Based on a set of criteria, a minimum of two researchers will code and assess the eligibility of the records. Examples of inclusion and exclusion criteria are briefly described as:

- Papers must be about chemistry education
- Papers must use a game-based learning approach only
- Games must use either digital media or a combination of digital and analogue media

- Student level must be equivalent to secondary or higher education
- Games must be accessible through a platform or by contacting the author

One way to distinguish between GBL and gamification is to look at the pedagogical scenario around the game. As “Gamification involves the addition of specific game features, mainly involving the reward system and narrative structure, to an existing (nongame) learning environment [...]” (Plass, Mayer and Homer, 2020), one can look at these characteristics to determine if a tool falls under the “GBL” or “gamification” category. Once this eligibility phase is completed, analysis of the extracted data will proceed.

3. Conclusion and Perspectives

Based on previous synthesis works, this work-in-progress systematic review tries to explore a narrower game and media type on the topic of games in chemistry education. Focusing solely on a digital game-based learning approach and using a systematic approach with the PRISMA framework, a search of different databases and journals (ERIC, SCOPUS, EBSCO, JCE, CERP) has been conducted. 2242 records were extracted and are currently being screened using titles and abstracts only to exclude non-relevant records. Future perspectives will include assessing the retained records using a set of eligibility criteria and the analysis of the extracted data.

Acknowledgements

The lead author would like to thank the co-supervisor of this research, Dr. Caroline Collette, in addition to Pr. Bernard Leyh, for their supervision, help and previous advice through this work.

Ethics Declaration: Ethical clearance was not required for this research.

AI Declaration: As the author is not a native English speaker, Microsoft Copilot was used solely for grammatical correction and language refinement. No AI tools were used for the generation of scientific content.

References

- Beaver, S. (2026) ‘Games for School: Educational Games – Easy Hard Science’. Available at: <https://learnwithdrscott.com/games-for-school-educational-games/> (Accessed: 5 August 2026).
- Becker, K. (2017) ‘Digital Game-Based Learning: Learning with Games’, *Choosing and Using Digital Games in the Classroom*. Cham: Springer International Publishing, pp. 25–62. Available at: <https://doi.org/10.1007/978-3-319-12223-6>.
- Becker, K. (2021) ‘What’s the difference between gamification, serious games, educational games, and game-based learning?’, *Academia Letters* [Preprint]. Available at: <https://doi.org/10.20935/AL209>.
- Byusa, E., Kampire, E. and Mwesigye, A.R. (2022) ‘Game-based learning approach on students’ motivation and understanding of chemistry concepts: A systematic review of literature’, *Heliyon*, 8(5), p. e09541. Available at: <https://doi.org/10.1016/j.heliyon.2022.e09541>.
- Elmali, S., Freund, L. and Tiemann, R. (2026) ‘A systematic literature review of game-based approaches in chemistry education (2014–2024)’, *Chemistry Education Research and Practice*, 27(1), pp. 31–44. Available at: <https://doi.org/10.1039/D5RP00248F>.
- Hu, Y. et al. (2022) ‘Game-based learning has good chemistry with chemistry education: A three-level meta-analysis’, *Journal of Research in Science Teaching*, 59(9), pp. 1499–1543. Available at: <https://doi.org/10.1002/tea.21765>.
- Mayer, R.E. (2014) *Computer Games for Learning: An Evidence-Based Approach*. The MIT Press. Available at: <https://doi.org/10.7551/mitpress/9427.001.0001> (Accessed: 20 May 2025).
- Page, M.J. et al. (2021) ‘The PRISMA 2020 statement: an updated guideline for reporting systematic reviews’, *Systematic Reviews*, 10(1), p. 89. Available at: <https://doi.org/10.1186/s13643-021-01626-4>.
- Papadakis, S. (2018) ‘The use of computer games in classroom environment’, *International Journal of Teaching and Case Studies*, 9(1), pp. 1–25. Available at: <https://doi.org/10.1504/IJTC.2018.090191>.
- Plass, J.L., Homer, B.D. and Kinzer, C.K. (2015) ‘Foundations of Game-Based Learning’, *Educational Psychologist*, 50(4), pp. 258–283. Available at: <https://doi.org/10.1080/00461520.2015.1122533>.
- Plass, J.L., Mayer, R.E. and Homer, B.D. (2020) *Handbook of Game-Based Learning*. The MIT Press.
- van Roy, R. and Zaman, B. (2017) ‘Why Gamification Fails in Education and How to Make It Successful: Introducing Nine Gamification Heuristics Based on Self-Determination Theory’, in M. Ma and A. Oikonomou (eds) *Serious Games and Edutainment Applications : Volume II*. Cham: Springer International Publishing, pp. 485–509. Available at: https://doi.org/10.1007/978-3-319-51645-5_22.
- da Silva, J.N.J. et al. (2025) ‘1925–2024: One Century of Educational Games in Chemistry’, *Journal of Chemical Education*, 102(4), pp. 1492–1510. Available at: <https://doi.org/10.1021/acs.jchemed.4c01238>.
- Xu, J.J. et al. (2025) ‘Effects of Game-Based Learning on Students’ Motivation in Chemistry: A Meta-analysis’, *Journal of Chemical Education*, 102(3), pp. 1117–1128. Available at: <https://doi.org/10.1021/acs.jchemed.4c01304>.