

Using AI and Cognitive Taxonomies to map Learning Processes in Board Games

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Abstract: Board Game-Based Learning (bGBL) has gained increasing attention as an innovative approach to foster active engagement and holistic cognitive development. However, integrating board games into effective practice is challenging, partly because of the lack of an established instructional framework. The implementation of bGBL often relies on teachers' personal initiative and familiarity with games, rather than on shared design practices. One of the main obstacles to implementing GBL lies in properly aligning learning goals with the actions that take place during gameplay, and the related learning processes. In this study, we develop a theoretical framework for aligning learning goals and the cognitive processes elicited by game mechanisms. We use this framework to train a GenAI assistant (GADbot) to assist bGBL instructional design, assessing its performance through human expert evaluation. Given the ever-increasing number of available board games and the constant innovation in game mechanics, this approach can revolutionize the field of bGBL, leveraging AI as an assistant to lower the entry barrier for teachers to choose the right game for their educational needs, thus providing the foundation to design meaningful learning experiences and advance active pedagogical practices.

Keywords: Board games, Instructional design, Artificial intelligence, Chatbot, RIZA

1. Introduction¹

In recent years, *Board Game-Based Learning* (bGBL) has gained increasing relevance as a teaching methodology capable of combining active engagement, experiential learning, and the development of cross-cutting skills (Gee, 2003; Plass, Homer & Kinzer, 2015). Thanks to their explicit structure and transparent rules, board games offer ideal conditions for observing cognitive processes in real time, making them privileged tools for designing authentic learning environments (Andreoletti & Tinterri, 2023). However, the introduction of bGBL in formal learning environments, such as schools and universities, is still sporadic and largely dependent on individual initiatives by teachers (Persico et al., 2019). Furthermore, most of these activities relegate games to recreational or mere exercise functions, coming short of realizing the full potential of board games as full-fledged learning environments (Cantoia, Clegg, and Tinterri, 2023). One of the main obstacles to implementing GBL lies in properly aligning (Biggs, 1996) learning goals with the actions that take place during gameplay, and the related learning processes (Arnab et al., 2015). In this sense, the cognitive functions activated by board games should not be seen as generic by-products of the activity, but as levers for achieving specific educational objectives. By identifying and mapping these functions, educators can intentionally design game experiences that target distinct learning outcomes in cognitive, disciplinary, and transversal domains. This is critical for effective implementation of bGBL, in-game and around-game assessments, and real-time calibration of the learning process (Andreoletti and Tinterri, 2023). This is the context for the contribution of Tinterri, Di Padova, and Pelizzari (2024), which proposes an integrated theoretical framework for analyzing and designing bGBL activities in an intentional and evaluable way. The model is based on three axes:

1. The taxonomy of Anderson & Krathwohl (2001), useful for classifying and designing oactivities based on the cognitive processes involved;
2. The R-I-Z-A model (Trinchero, 2017; 2018), which describes the executive functions activated in complex educational contexts (representation, interpretation, activation zone, self-regulation);
3. The concept of situated competence (Le Boterf, 2000), understood as the integrated mobilization of knowledge, skills, and attitudes in meaningful contexts.

¹The paper was conceptualized and developed collaboratively by all authors, with each contributing to specific sections based on their expertise. A.T. was responsible for writing sections Results and Conclusion. M.d.P. authored section Material and methods and Discussion. F.P. authored section Introduction and Theoretical Framework.

These three axes make it possible to overcome reductive views of playful learning, providing an operational model for the design and evaluation of activities. In particular, the R-I-Z-A model allows us to observe play as a sequence of micro-cycles of interpretation, action, and reflection, consistent with the experiential learning paradigm (Kolb, 1984) and with the definition of open-ended problems (Trinchero, 2012). This makes play not only a space for practice, but also for the active construction of skills. Starting from this framework, the present study aims to develop a further level of formalization by proposing a generative artificial (GenAI) intelligence-based support system for the automatic mapping between game mechanics and cognitive processes. The goal is to provide a scalable tool that helps teachers and designers select games consistent with specific educational objectives, democratizing access to bGBL and facilitating instructional alignment (Biggs, 1999; Arnab et al., 2015). This approach, which combines established theory and emerging technology, represents a step towards an evidence-based pedagogy capable of harnessing the educational potential of games, not only as a motivating activity, but as a structured space for the development of critical thinking, cooperation, and self-regulation (Shute & Ventura, 2013; Barab et al., 2010).

2. Theoretical Framework

The framework is based on three theoretical axes: (1) Anderson & Krathwohl's taxonomy (2001); (2) the R-I-Z-A neuroeducational model (Trinchero, 2017; 2018); (3) Le Boterf's construct of situated competence (2000). Anderson and Krathwohl's (2001) revision of Bloom's taxonomy proposes a two-dimensional matrix that crosses cognitive process levels (remembering, understanding, applying, analyzing, evaluating, creating) with types of knowledge (factual, conceptual, procedural, metacognitive). This model allows not only the classification of educational objectives but also the design of activities consistent with them (Biggs, 1999). In the bGBL context, this taxonomy allows the mapping of cognitive processes activated by game mechanics (Engelstein & Shalev, 2019), making the link between game rules and educational objectives visible. Some mechanics—such as narrative choice, prisoner's dilemma, or simultaneous action selection—activate high levels of the taxonomy, promoting reflection, critical evaluation, and the generation of new solutions (Wouters & van Oostendorp, 2017).

The **R-I-Z-A** model, developed by Trinchero (2017; 2018), was created in the context of neuroeducation with the aim of mapping and enhancing the executive functions involved in complex educational contexts. It is divided into four dimensions:

- Resources: mental construction of patterns, rules, meanings;
- Interpretation: active decoding of the context and available information;
- Activation zone: experimentation between the known and the new;
- Self-regulation: conscious monitoring and regulation of one's own actions.

In the context of bGBL, R-I-Z-A proves to be a dual tool: descriptive and formative. On the one hand, it allows educators to observe precisely how players activate complex cognitive strategies during play; on the other hand, it stimulates metacognition, thanks to reflection on how the game was played (Trinchero, 2012). The correspondence between playful dynamics and cognitive structure is based on the idea of play as an open problem: each game involves continuous cycles of interpretation-action-reflection that mirror the experiential learning cycle (Kolb, 1984; Trinchero, 2017). In games such as *Just One* or *Dixit*, for example, the player must:

- Represent internal rules and objectives (semantic or strategic);
- Interpret ambiguous signals, implicit communications, and the movements of others;
- Act by choosing between several possible strategies with different outcomes;
- Self-regulate based on the feedback received, adapting their behavior.

This recursive sequence (interpretation, action, reflection) allows us to observe both micro-decisions (tactical) and macro-strategies (strategic), providing qualitative evidence of the learning process (Gobet, Retschitzki & De Voogt, 2004). The third theoretical axis is based on the concept of **competence as a situated construct**, proposed by Le Boterf (2000, 2006). Competence is not simply the sum of knowledge and skills, but the dynamic articulation between:

- *Savoir*: theoretical knowledge;
- *Savoir-faire*: operational skills;
- *Savoir-être*: relation and attitude.

In play, these aspects emerge simultaneously: the player mobilizes prior knowledge, acts in complex situations, and interacts with other subjects in a regulated but open context (Lave & Wenger, 1991). Learning takes place through legitimate and progressive participation in meaningful practices, as illustrated in the concept of *playful apprenticeship* (Barab, Gresalfi & Ingram-Goble, 2010). This theoretical framework allows us to overcome reductive views of playful learning, anchored solely in motivation or participation, and instead proposes an analytical reading of game dynamics as highly cognitive training spaces. In this perspective, the mechanical transparency of board games (i.e., the visibility of rules and the effects of actions) is a pedagogical advantage: it allows players to reflect on decisions and strategies, facilitating metacognition and formative assessment. However, the systematic adoption of bGBL in formal educational contexts remains limited. Among the main obstacles is the difficulty of aligning game mechanics with educational objectives and expected cognitive processes, often due to a lack of shared theoretical and operational tools (Sousa et al., 2023; Persico et al., 2019). The risk, therefore, is that the use of games remains confined to a motivational dimension, without effective integration into learning pathways. As highlighted by Arnab et al. (2015), one of the central hubs of Game-Based Learning consists in the alignment between game mechanics and learning mechanics (LM-GM mapping). However, in practice, this alignment remains difficult to implement in the absence of shared and accessible models to guide design and evaluation. Some notable attempts in this direction include the model by Garris, Ahlers, and Driskell (2002), the principles of evidence-centered design (Mislevy et al., 2014), and more recently, the framework proposed by Tinterri, Di Padova, and Pelizzari (2024). This work is in line with the theoretical framework outlined above, fitting into this theoretical framework with the aim of automating the process of mapping game mechanics and cognitive processes through the use of artificial intelligence. In particular, it aims to systematize and scale this process through the development of an AI assistant capable of associating game mechanics with cognitive processes according to the A&K taxonomy, automating the most intensive phase of instructional design. AI is conceived here not as a substitute for the teacher, but as a *digital scaffold* to facilitate the design of bGBL experiences consistent with stated educational objectives (Arnab et al., 2015; Gómez Niño et al., 2024). This choice is based on two main objectives: (1) board games offer a structured and iterative environment, ideal for analyzing the link between action and learning, but it is necessary to generate a database that allows, over time, to refine the alignment models between game dynamics, cognitive processes, and assessment strategies; (2) the combination of established theoretical models and advanced digital tools can break down barriers to the adoption of bGBL, providing teachers and educational designers with concrete tools to select, adapt, and evaluate games according to educational objectives. In this way, game design is no longer left to individual intuition, but anchored to validated theoretical models and observable evidence (Mislevy et al., 2014; Shute & Ventura, 2013).

3. Aim of the Study

The goal of this study is to develop a GenAI assistant to help teachers design bGBL activities that (a) fully employ the learning potential of games (b) define expected learning outcomes according to the theoretical framework described above (c) include suggestions for personalization of the activity according to the learner specific needs. This paper describes the process of designing a first prototype of the assistant Game Analysis and Design (GAD)Bot and discussion of the early outcomes of the Bot.

3.1 Material and Methods

Desired Functions of the Chatbot: GADBot was conceived as a pedagogical assistant to support teachers, educators, and instructional designers in the intentional design of board game-based learning (bGBL) activities. Its core function is to suggest appropriate games by analyzing a complex set of educational variables, including the target student profile, the subject area, the learners' previous experience with bGBL, the intended learning objectives, and the presence of students with specific learning needs. Rather than simply recommending games, GADBot activates an inferential process that maps game mechanics to cognitive processes and situated competences. The system is capable of assessing students' age, cognitive development, and familiarity with games, thereby selecting titles that are appropriate in terms of complexity, social interaction, and accessibility. By leveraging the theoretical models discussed in the article—specifically Anderson and Krathwohl's taxonomy and Trinchero's R-I-Z-A model—GADBot links in-game actions to activated cognitive operations, and formulates suggestions oriented toward measurable learning outcomes. Simultaneously, the chatbot accounts for inclusion-related constraints, offering adaptation strategies aligned with Universal Design for Learning (UDL), such as simplified rules, role redistribution, and multimodal supports (Rao, Torres & Smith, 2021). In this way, GADBot operates as a flexible and theory-informed design tool that adapts to diverse educational contexts without compromising pedagogical rigor.

Design of the Chatbot: GADBot was developed as a Custom GPT within the OpenAI platform, following a modular architecture that supports dialogue-based educational design (Nyaaba & Zhai, 2024). The interaction begins with user input describing the learning context, goals, classroom profile, and any relevant constraints. These inputs are processed by a semantic reasoning engine that queries a structured and annotated dataset of board games, sourced from BoardGameGeek.com and enriched with educational metadata. The chatbot’s inferential core enables it to select suitable games based on a cognitive matrix that links gameplay mechanics to executive functions, cognitive verbs, and situated learning processes. From this selection, GADBot generates a complete learning activity divided into phases—preparation, gameplay, and reflection—specifying for each phase the learning goals, student tasks, timing, assessment methods, and inclusive strategies. A metacognitive function is also embedded: GADBot can self-assess the coherence of its proposals with the user-defined objectives and provide a concise summary of the activity for validation (Hutson & Plate, 2023). The assistant operates in both English and Italian, adapting its technical register based on user expertise and, when appropriate, referencing relevant pedagogical frameworks such as constructivism, experiential learning, and gamification. GADBot thus functions not only as a recommender but also as a design mediator between theory and practice, between cognitive models and instructional constraints (Honig, Desu & Franklin, 2024).

Training of the Chatbot: The training of GADBot followed a multi-phase process (Liu et al., 2023; Arora et al., 2022; Bibauw et al., 2022) aimed at constructing an assistant capable of integrating validated theoretical models, structured empirical data, and realistic educational scenarios. Its knowledge base combines regulatory and pedagogical sources—including the full body of Italian school legislation, Anderson and Krathwohl’s taxonomy, Trinchero’s R-I-Z-A model, and Le Boterf’s notion of situated competence—with a curated and continuously updated dataset of board games from BoardGameGeek.com. This dataset includes detailed information on mechanics, player interaction, age range, duration, accessibility, and community feedback. The identification and classification of game mechanics is based on the framework developed by Engelstein and Shalev (2019), which offers a comprehensive systematization of the core dynamics found in modern board games. These mechanics were used to annotate a selected subset of games, each of which was then aligned with specific cognitive processes and executive functions. This mapping enabled the chatbot to associate game structures with learning outcomes in a coherent and theory-informed manner. The assistant was refined through iterative tuning via simulated dialogues with teachers, where requests included game analyses, comparative evaluations, inclusive learning activity proposals, and assessment planning. GADBot’s responses were evaluated using a dedicated rubric with four dimensions—activity structure, game selection, learning objective definition, and personalization suggestions (Table X)—which facilitated continuous improvement of its pedagogical alignment and reasoning capabilities. When the proposed game is not found in the dataset, GADBot activates an analogical reasoning protocol, requesting additional details (e.g., game mechanics, duration, number of players) and proposing comparable games for inference. As a result, the system functions as a scalable and pedagogically-grounded assistant, capable of supporting the intentional construction of meaningful and inclusive learning environments.

Analysis of Chatbot responses: To evaluate the responses obtained from GADBot, a rubric was developed including three main criteria: the structure of the proposed activity, the choice of the game, the learning objectives, and personalization suggestions. Each criterion included three indicators which were rated on a four-level scale, from “excellent” to “insufficient” (Table 1). The responses were analyzed independently by three experts with years of experience in the field of bGBL and provided as feedback to GADBot for further refinement.

Table 1: The criteria and indicators used for evaluating the output of GADBot

Criteria	Indicator
Structure of the activity	The phases of the activity are clearly defined
	The phases of the activity are aligned with the learning goal(s) provided by the user
	The activity can realistically be implemented in the given context
Choice of the game	The game of choice is appropriate for the students' age and experience
	The game mechanics are described correctly

Criteria	Indicator
	The gameplay is aligned with the learning objectives
Definition of learning objectives	The learning objectives follow the R-I-Z-A model
	The learning objectives are attainable within the proposed activity
	The learning objectives are aligned with the learning goal(s) provided by the user
Personalization	The personalizations proposed can be realistically implemented
	The personalizations proposed are coherent with the students profile
	The personalizations proposed enhance the inclusiveness of the activity

3.2 Results

The GADBot tool is still in a work in progress phase as it keeps being trained for accuracy, therefore a comprehensive analysis of its output is outside the scope of this contribution. However, this section describes a sample output for a GADBot interaction and the feedback received from the human evaluators. GADBot was asked to design an educational activity based on the following prompt:

Suggest a board game for a learning activity for students 5th class of the Primary school, on the topic of: the fall of the Occidental Roman Empire and the "romanic-barbaric reigns". The students have very limited experience with playing games in the classroom. The expected learning outcomes are "recognize the traces of the past in one's own social and geographic context" and "knowing and analyzing the main historic events". Also, the activity should be personalized for a student with mild cognitive impairment.

After the chatbot provided its answer, it was asked to self-analyze its answer by asking:

In your opinion, is this activity aligned with the learning goals which were provided?

Following this prompt, the ChatBot analyzes its output and provides corrections. In some instances, the chatbot observed that the activity was not entirely aligned with the learning goals and provided corrections. In this case, however, GADBot found that the activity was well aligned with the learning goals provided. Finally, a third prompt requested the Chatbot to summarize the activity (Table 2). The output of this prompt was provided to four human bGBL experts to evaluate the quality of the activity created by the bot.

Table 2: Summary of a sample activity proposed by GADBot

Title	The Fall of an Empire: Building the Timeline of the Roman-Barbarian Kingdoms
Context	Class: 5th grade primary school Setting: classroom with tables arranged in small groups (3–4 students per group) Timeframe: 2 lessons of 60 minutes each Prerequisites: basic knowledge of Roman civilization, understanding of chronological order Game experience in classroom: minimal One student with mild cognitive impairment (MCI)
Learning goals	Key European Competences Cultural awareness and expression Historical competence (based on Italian National Guidelines, 2012) Learning Goals for History (5th grade) Identify historical traces in the local environment.

Title	The Fall of an Empire: Building the Timeline of the Roman-Barbarian Kingdoms		
	Know and sequence key events from ancient history. Specific Learning Objectives Place events and civilizations in time and space. Reconstruct simple historical sequences. Recognize visual and material sources.		
Expected outcomes	Learning Action	RIZA Descriptor	Cognitive Level
	Recognize elements from Roman and Barbarian worlds	Recognize	Remember
	Order key events related to the fall of the Empire	Select – Locate	Understand – Analyze
	Build a shared timeline	Represent – Collaborate	Apply – Create
Structure of the activity	PHASE 1 – Introduction and knowledge activation Guided discussion with visuals (Roman soldier, Visigoth, Empire map) Stimulus questions: “Who were the barbarians?”, “What happens when an empire falls?” Duration: 15–20 min PHASE 2 – Cooperative game: simplified Timeline Each group receives historical cards (e.g. “410 AD: Sack of Rome”, “476 AD: Romulus Augustulus abdicates”) Students work to place cards in chronological order Visual aids used (icons, simple captions) Duration: 30 min PHASE 3 – Debriefing and collective discussion Timeline reviewed as a class Reflective questions: “What does this sequence tell us?”, “Who were the key figures?” Duration: 15 min PHASE 4 – Authentic task Each group creates a new event card or a historical comic strip A synthesis and creativity task with teacher support Duration: 40–60 min		
Inclusion	Large, high-contrast images, concept maps, simplified language Group placement with peer tutor, step-by-step instructions, extra time Use of cut-out visuals, verbal or drawn responses instead of written		
Materials	Timeline cards (original or customized) Physical or wall-mounted timeline Historical maps and images Visual aids and scaffolding sheets Posters, scissors, markers for final task		
Assessment	Formative	Ongoing observation grid	Participation, cooperation, historical vocabulary usage

Title	The Fall of an Empire: Building the Timeline of the Roman-Barbarian Kingdoms		
	Self-assessment	Simplified form	“What did I understand? Where did I need help?”
	Summative	Final product (card or comic) + oral explanation	Historical accuracy, creativity, sequence coherence

The activity was then rated independently by three human experts using the aforementioned rubric (Figure 1).

Indicator	Rating			
	Excellent	Good	Sufficient	Insufficient
The phases of the activity are clearly defined				
The phases of the activity are aligned with the learning goal(s) provided by the user				
The activity can realistically be implemented in the given context				
The game of choice is appropriate for the students' age and experience				
The game mechanics are described correctly				
The gameplay is aligned with the learning objectives				
The learning objectives follow the R-I-Z-A model				
The learning objectives are attainable within the proposed activity				
The learning objectives are aligned with the learning goal(s) provided by the user				
The personalizations proposed can be realistically implemented				
The personalizations proposed are coherent with the students profile				
The personalisations proposed significantly enhance the inclusiveness of the activity				

Figure 1: Summary of the sample activity evaluation by independent bGBL experts

Overall, the evaluators were satisfied with the quality of the activities proposed by the tool. The chatbot was able to provide clearly structured activities, using games that were appropriate for the context, using the RIZA framework to define learning objectives in line with the learning goals and largely attainable within the activity. Still, depending on the activity, the chatbot answers were sometimes not entirely aligned with the learning objectives, or the game was tangential to the activity rather than as its focal point. Furthermore, due to the well documented variability of the technology (Tinterri et al, 2024) in a few occasions the answers of GADbot were missing parts of the required information, which could be obtained through further prompts.

4. Discussion

Despite supporting evidence by the scientific literature, board game-based learning (bGBL) is very seldom employed in schools and other formal learning environments. This is due in part to the complexity of game-based instructional design, which requires both knowledge of games and game pedagogy, and to the lack of an established pedagogical framework for bGBL instructional design. In this study, we have developed a theoretical framework and used it to train a Generative AI chatbot (GADbot) designed to support teachers. While still in a prototyping phase, the early returns of the bot have been positively rated by human bGBL experts, while providing feedback for further training of GADbot. But whereas the approach seems promising to obtain high

quality, personalised assistance for teachers trying their hand at using bGBL, there are some limitations that need to be addressed. First, the tool has not received an extensive assessment; to this aim, a more comprehensive analysis of the bot output must be realized. Second, the tool must be validated not only by bGBL experts but also by actual teachers, to understand whether its output is not only scientifically sound but also helpful for classroom implementation. Third, the bot should not be perceived as a substitute for teacher effort to develop mastery of bGBL instructional practices, but rather as an assistant and support tool to enhance its impact, allowing her to autonomously research and experiment with bGBL. Fourth, the ethical and effective use of artificial intelligence tools requires specific competence, to avoid the “garbage in, garbage out” phenomenon and obtain quality answers (Cuomo, 2023); thus, teachers and educators should receive specific training on AI functioning and prompting strategies to maximize the potential of GADbot. Finally, further research should be conducted to evaluate the effectiveness of GADbot-assisted learning activities in real-life scenarios, addressing not only teacher perceptions but also the learning outcomes that can be achieved by students and the implications of bGBL use in educational contexts. Future research is thus required to answer the following questions: a) is GADbot perceived by teachers as a helpful tool for bGBL design? b) to which measure are activities designed with GADbot effective in terms of student learning achievements? c) how can GADbot be effectively integrated in teacher bGBL training?. Taken together, this study combines advancements in the field of GBL with innovation in AI-assisted learning design, with the aim of making bGBL more appealing to educators and instructional designers; this contribution, albeit promising, is then just a first step in a path with the potential to make bGBL, and its tantalizing potential for learning, accessible to a larger audience.

5. Conclusions

As the interest of both the general public and academic research on the educational effectiveness of board games is on the rise, the potential of generative artificial intelligence for learning could provide innovative solutions to the longstanding problem of how to effectively implement board game-based learning in traditional educational settings. The GADbot assistant, built upon a solid theoretical framework, shows intriguing potential and could be a game-changer for teachers and educators with an interest in bGBL but limited by their lack of knowledge of games; however, further research and empirical validation is required to improve this tool and evaluate its effectiveness in real-life situations.

Ethics declaration: The study adheres to relevant data protection regulations and ethical guidelines governing research involving human participants.

AI declaration: Artificial intelligence (AI) tools were used to support the preparation of this manuscript. Specifically, ChatGPT (OpenAI) was used to build the GADbot tool described and analysed in the study. The body of the paper includes content generated from the chatbot to illustrate its output.

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