# LogiCraft: A Game Modification Framework for Learning Propositional Logic

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## Abstract

Logic and formal reasoning are essential skills for programming and computer science. Still, they are challenging to teach due to their abstract nature. This paper explores how Game-Based Learning (GBL) can simplify logic concepts, making them interactive and engaging for young learners. We introduce *LogiCraft*, an educational framework for co-designing board games that teach propositional logic. The framework includes three illustrative tile-based board games: ¬SCR∧BL, *Tautoblocks*, and *Deducto*. These games teach propositional logic by merging computational thinking with hands-on gameplay. By integrating syntax and semantics in new ways, ¬SCR∧BL focuses on logic formulas construction and truth tables visualization, *Tautoblocks* introduces more advanced concepts of negation, tautology, and contradiction, and *Deducto* highlights translation and model-based reasoning. Playtesting sessions with students and teachers suggest that our games can enhance logic skills and promote cooperative learning. Our initial classroom results show potential for broader applications in game-based learning.

## CCS Concepts

• **Applied computing** → **Education**; **Interactive learning environments**; **Computer games**.

## Keywords

propositional logic, game-based learning, board games, education

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## 1 Introduction and Background

The teaching of propositional logic faces longstanding challenges. Traditional methods often present logic as a highly abstract and technical subject, making it difficult for students to grasp. The reliance on formal notation, rote exercises, and isolated problem-solving further exacerbates disengagement. Yet, as computational thinking is increasingly emphasized in educational curricula—such as the updated Dutch *kerndoelen*—it is essential to address these challenges with innovative pedagogical tools [8, 33].

Declining mathematics proficiency among high school students in the Netherlands underscores the urgency of developing engaging, interdisciplinary teaching methods [31]. Effective approaches should not only make logic accessible but also contextualize it within the broader domains of mathematics [4], philosophy [2, 27], and computer science [7].

Game-Based Learning (GBL) studies how games and play can help improve learning experiences [22]. While various GBL approaches exist for teaching STEM subjects [19], none of them specifically targets logic. In this context, a particularly promising approach is to teach subject matter through game design and play of board games [20]. Instead of prescribing what learners should do and how, educators, game designers, and learners collaborate in an iterative co-design process, modifying "half-baked games" to discover how to improve learning experiences together.

We investigate how board games can enhance computational thinking, promote practical applications, boost students' engagement and autonomy, and foster interdisciplinary connections, e.g., with mathematics, computer science, and philosophy. Our main goal is to demystify logic through interactive play and co-design.

To achieve this, we propose *LogiCraft*, a game-based educational framework that uses tile-based games to teach logic through interactive play. LogiCraft takes the shape of a so-called *piecepack*, a reusable set of tile pieces and a playing board for creating a variety of logic games. By involving learners into the co-design process, logic games transform abstract concepts into hands-on intuitive experiences [17, 34].

This paper introduces the *LogiCraft* framework, describes its three standalone games—*¬SCR∧BL*, *Tautoblocks* and *Deducto*—and discusses preliminary empirical observations from playtesting. Our contributions include:

(1) *LogiCraft*: a structured framework for designing educational logic games through co-design.
(2) The designs of logic games, *¬SCR∧BL*, *Tautoblocks*, and *Deducto*, that demonstrate how to apply the framework.

## 2 Related Work

We begin by relating practical challenges in teaching logic to the state-of-the-art in *Game-Based Learning* (GBL).



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## 2.1 Teaching STEM courses

Teaching STEM subjects is challenging due to their inherent abstract nature. Logic in particular, relies on formal symbols, truth tables, and rigid syntactic rules, which especially at the beginning make logic less accessible to some learners. They may feel overwhelmed by its abstract nature and lack of immediate relevance to their everyday life experiences or goals. This alienation diminishes students' motivation and engagement [28].

Most traditional teaching methods exacerbate the issue by emphasizing rote memorization and repetitive exercises, which fail to foster critical thinking or demonstrate logic's practical applications. As a result, students rarely connect logical formulas to real-world contexts, leaving them questioning the subject's relevance [2, 17]. Another major limitation of traditional logic instruction is its solitary nature [25]. Students often work independently, missing opportunities for dialogue, mutual problem-solving, and collaborative learning, which are crucial for building teamwork skills applicable in software development and interdisciplinary fields.

Additionally, traditional curricula are often rigid, offering little room for personalization or creativity. Learners with diverse needs, particularly those who benefit from hands-on or visual approaches, are left at a disadvantage [6, 14]. Without inclusive tools or methods, many students risk falling behind, reinforcing the notion that logic is a subject for a select few [1]. These barriers significantly limit engagement, comprehension, and retention, highlighting the need for innovative strategies that make logic education more accessible, collaborative, and relevant.

## 2.2 Game-Based Learning

*Game-Based Learning* explores how games and play can enhance students' learning experiences [21]. Board games have been identified as a potential solution for teaching STEM subjects with engaging tactile turn-based mechanisms [20, 26]. However, integrating learning goals with game-play objectives is challenging. As a result, designing board games that offer quality learning experiences is particularly complex [24]. Related work addresses this as follows.

The analogue *Game Modification Framework* (aGML) proposes adapting existing tabletop games, in particular board games, to educational needs [20]. The framework provides educators with a template language for describing modifications, lessons, and progressions. Our work is also analogue, but takes a more playful approach that involves the learners in modifying board game designs.

We end this section by mentioning a few examples of known logic games and how they relate to *LogiCraft*.

*The Logic Game* is a two-player card game for learning the semantics of propositional logic [11]. *LogiCraft* also emphasizes propositional logic semantics through its rules, but instead introduces a modifiable board game that integrates the use of logic rules with the game-play. Visual representations of rules (i.e., "logic pies" see Figure 3) simplify formal notation, making the semantics of logical operators more intuitive and approachable.

*TrueBiters* is a digital game designed for learning truth operators based on the two-player competitive card game *bOOleO* [29]. Players fill an inverse pyramid of tiles with cute monster pieces representing logical operators. Starting from a predefined top line of bits, they solve the puzzle in a top-down manner. *LogiCraft* uses a square board instead, and centers around forming correct patterns of atoms and operators to form logical clauses.

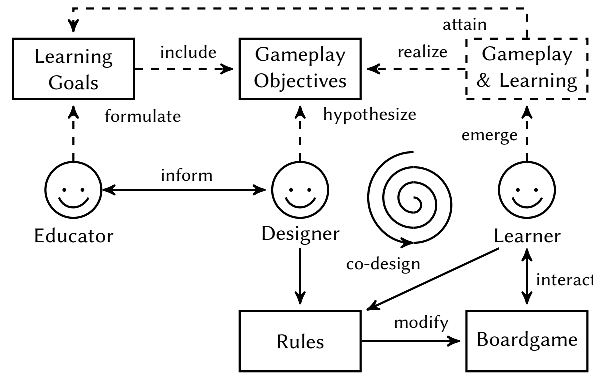


**Figure 1: *LogiCraft*: A Logic Game Modification Framework**

## 2.3 Co-design Methodology

*Co-design* is a teaching method where educators and learners collaborate in the design process to create high-quality solutions [23]. This approach allows students to engage socially while solving logical challenges. Whether competing or working cooperatively, players strategize, discuss, and learn from each other. This approach naturally encourages teamwork and critical thinking. Such social learning mirrors real-world contexts, where logic is applied in collaborative settings like programming and problem-solving in AI [5]. Crucially, the *co-design process* empowers students by involving them in creating games [9, 15, 20]. This active participation not only enhances the games but also deepens students' connection to the material, fostering a sense of ownership in their learning journey [12, 20].

In this paper, we conduct *design research*, an iterative method that explores how to design and improve solutions in practice [10]. This method integrates particularly well with participatory co-design and qualitative analysis, ensuring continuous improvement through collaboration. We shall describe how feedback from high school and university students has shaped our games' design to ensure that they are engaging, intuitive, and aligned with students' needs.

## 3 *LogiCraft* Framework

The *LogiCraft* framework provides a structured approach for co-designing "logic board games" that integrates learning goals with game-play objectives. Its main aim is to connect learners and educators using game mechanics that actively promote understanding of and engagement with propositional logic. This goal is achieved by transforming abstract concepts into a hands-on, tactile, visual and interactive activities. These games provide a low-pressure, enjoyable environment where learners can explore propositional logic hands-on. The framework adopts a co-design approach that involves modifying tile-based games to improve learning experiences.

The diagram in Figure 1 presents an overview of this co-design approach. Before explaining its components, we first clarify the problem scope and the main hypotheses.

## 3.1 Problem description

The development of the *LogiCraft* framework is guided by the following challenges, research objectives, and hypotheses.

*3.1.1 Challenges.*

- How can board games effectively engage learners with logical operators and advanced logic concepts in a group setting?
- How can educators use these games to guide the learning process while preserving rigor and accuracy?
- What design principles ensure that game-play aligns with learning goals?

*3.1.2 Objectives.*

- Develop a scalable and flexible framework that can be adapted to different classroom contexts.
- Ensure that games address key learning objectives, such as understanding logical connectives, constructing formulas, and applying propositional logic in real-world scenarios.
- Promote collaboration and competition to sustain engagement and motivation.

*3.1.3 Hypotheses.*

H1 Board games can make propositional logic more engaging and accessible in group settings by providing visual and tactile learning tools.

H2 Educators can use board games to guide the logic learning process in a structured yet playful manner, fostering computational thinking and problem solving skills.

## 3.2 Core components of the framework

The *LogiCraft* framework encompasses key stakeholders, essential learning tools, and structured artifacts that facilitate both the design and application of logic games in educational contexts.

*3.2.1 Stakeholders: Different Perspectives on Logic Learning.* The framework integrates three primary perspectives, each contributing to the development and implementation of logic-based learning:

- **Educators.** Teachers use the framework as a tool to introduce and reinforce logic concepts in an engaging, hands-on manner. By incorporating game-based learning into their curriculum, educators can make abstract logic principles more accessible and interactive.
- **Game Designers.** The framework provides principles for designing logic games that align with educational objectives. These tools are used by *designers* (i.e., students and teachers who guide the design of the game) who ensure that the game is both educational and enjoyable.
- **Learners.** Students engage with logic through both co-design and game-play, allowing them to explore concepts actively rather than passively absorbing information. Their role in shaping and playing the game enhances their motivation and deepens their conceptual understanding.


**Figure 2: A simple disjunctive formula**

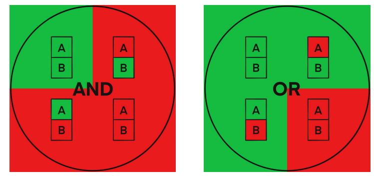


**Figure 3: Logic pies: AND, OR**

*3.2.2 Means: Tools for Learning Logic.* To support logic learning, the framework provides a reusable board game system with dynamic components that allow for flexible game-play and adaptation across different learning contexts. The core tools include:

- **A simple board.** A simple board that can be adapted to different logic exercises and learning goals.
- **Puzzle pieces.** Puzzle-like tiles that represent logic operators and atoms that fit together to form logical statements (see Figure 2).
- **Logic pies.** These playing cards serve as visual aids (or cheat sheets) that replace traditional truth tables, illustrating how logical connectives combine and interact. These provide visual mechanisms and rules for applying operators, enabling students to construct, manipulate, and analyze logical formulas within a game setting. They simplify truth tables using intuitive diagrams (see Figure 3).

These components serve as the basic tools to help game-designers keeping game-play engaging and interactive.

*3.2.3 Artifacts: Learning Through Play.* The *LogiCraft* framework connects logical learning to game-play through three key artifacts:

- **Learning Goals.** Clearly defined educational objectives guide how players interact with logic operators in a meaningful way. These include: constructing valid logical formulas, understanding the relationships between different operators, and recognizing tautologies and contradictions.
- **Mechanisms.** Rules and constraints determine how players place board pieces ensuring that actions in the game reflect logical reasoning. These mechanisms scaffold learning by making logic rules tangible and easy to experiment with.
- **Playtesting and Iterative Design.** Structured game-play sequences provide opportunities for students to learn through direct interaction. Playtests help refine the learning experience, ensuring the game remains both effective and engaging.

Together, these elements form a comprehensive framework for teaching logic through play, fostering engagement, critical thinking, and hands-on learning.

**Figure 4: A co-design session at Kinkerbuurt Basisschool Amsterdam with AUC logic students**

## 3.3 Co-Design Method

The *LogiCraft* framework embraces an iterative co-design methodology, where students (both high school and university), teachers, and game designers collaborate at different stages of the game development process. This participatory approach ensures that the games remain engaging, educationally effective, and adaptable to diverse learning needs. Rather than imposing fixed rules, we adopt a flexible, evolving design philosophy, allowing the game-mechanics to change dynamically through play.

At the core of this methodology is the idea that games are never fully finished but continuously refined through player interaction. Inspired by concepts such as *half-baked games* and *game modding*, we view rules as fluid, subject to modification and expansion based on real-world classroom experiences [12, 13, 16]. Students and educators are encouraged to experiment with the mechanics of the games, suggest rule adjustments, and explore alternative ways of structuring game-play. This approach fosters a deeper understanding of logic—not just through play but through the process of designing, adapting, and refining the rules themselves.

Our three current games—originally conceived as a single, unified system—diverged into independent games through iterative play. Each iteration highlighted distinct learning challenges and opportunities, leading to the development of separate yet complementary games, each focusing on different aspects of logic. This organic evolution reflects the strength of learning through design, where the act of shaping the game becomes an integral part of the educational experience [18].

*3.3.1 Stages and Roles in the Co-Design Process.* The iterative development of *LogiCraft* follows a structured yet flexible three-stage process, with distinct roles for educators, designers, and learners:

(1) **Formulating Learning Goals (Educators)** – The process begins with defining the key educational objectives. Educators determine which logical concepts should be introduced, reinforced, or assessed through game-play, ensuring alignment with curriculum needs.
(2) **Co-Designing Rules to Achieve the Goals (Designers, Educators, and Learners)** – The game's mechanics are developed collaboratively, with all stakeholders contributing insights on how best to integrate logic concepts into engaging game-play. Students play an active role in shaping the experience, ensuring that the games are both intuitive and fun while remaining educationally effective.
(3) **Playtesting and Iterative Refinement (Learners and Educators)** – The games are repeatedly tested in classroom settings and informal play sessions, with students and teachers providing feedback on usability, difficulty balance, and engagement. Rule modifications emerge naturally as players identify challenges, suggest improvements, and refine strategies. This cycle of testing and revision ensures continuous improvement and adaptation (see Figure 4).

By embedding co-design into the learning process, students develop not only logical reasoning skills but also creativity, problem-solving abilities, and a deeper sense of agency in their education. This method transforms the act of learning into an interactive, evolving experience, demonstrating that logic is not a static set of rules to be memorized but a dynamic system that can be explored, modified, and mastered through play.

The *LogiCraft* framework underpins the design of our games *¬SCR∧BL*, *Tautoblocks*, and *Deducto*, demonstrating how its principles translate into practical educational tools: Each game illustrates how the framework supports the development of educational games that are both engaging and pedagogically sound.

# 4 *¬SCR∧BL*: a cooperative game for beginners

*¬SCR∧BL* is a scrabble-like cooperative game designed to adapt to learners at different learning stages, with the primary objective of constructing as many valid logical formulas as possible before running out of tiles. It introduces key logical concepts step by step, ensuring a smooth learning progression from simple formulas to more complex structures.

## 4.1 Formulating Learning Goals

Specific learning objectives of *¬SCR∧BL* include:

(1) **Understanding the Semantics of Propositional Logic Connectives**: Players use logic pies, simplified visual representations of truth tables, to grasp the behavior of logical operators (AND, OR, IF THEN) (see Figure 3)
(2) **Constructing Simple and Complex Logical Formulae**: Players place colored tiles representing atoms and connectives on the board, following syntactic rules and using parentheses for more complex formulas. (see Figure 6)
(3) **Exploring Interactions Between Logical Connectives**: The game mechanics encourage incremental learning, where smaller formulas are combined into more complex ones, deepening players' understanding of the structure of logic sentences and interaction between logical operators.

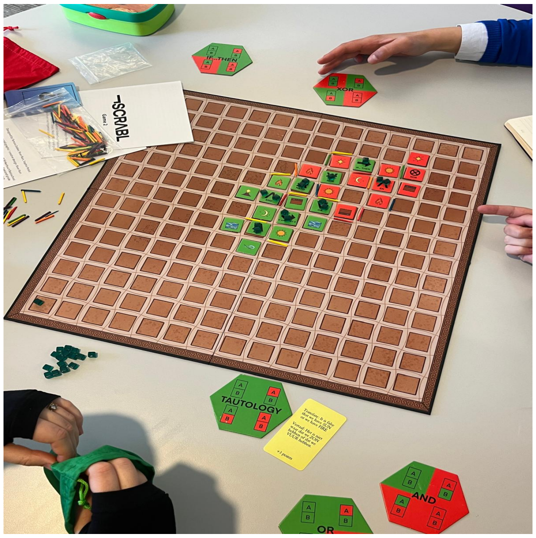


**Figure 5: Playing ¬SCR∧BL at Hyperion Lyceum**

(4) **Introducing Composite Operators (XOR, NOR, NAND)**: Since non-classical connectives play a significant role in programming and logic circuits, these are included and visually represented on the back of classical operators.
(5) **Emphasizing the truth-functionality of logical connectives, abstracting away from content**: the game should demonstrate that logical connectives behave as truth-functions, where the truth-value of a complex formula is a function of the truth-value of its components (atoms).

Additionally, the game is designed with specific pedagogical and game-play goals in mind:

- Making logic intuitive through visual encoding.
- Encouraging collaboration and team work in a shared problem-solving environment.
- Ensuring ease of use, so it can be played in a standard 45-minute class period.
- Being accessible to beginners, requiring no prior formal logic training.
- Bilingual: accessible to Dutch as well as English speaking students

## 4.2 Co-Designing Rules

*4.2.1 Co-design approach in* ¬SCR∧BL. *¬SCR∧BL* was developed using a co-design approach, involving high school students (ages 10-14), Amsterdam University College (AUC) students, and logic teachers from universities and secondary schools.

Throughout the co-design process, we explored various ways to make logic more intuitive and game-play more engaging:

- Logic Pies were introduced based on student feedback to visually represent truth tables.
- Colour-coding for truth values (red = false, green = true) was debated at different stages before becoming a core mechanic.
- We decided to distinguish the truth-value of a formula by representing it by red/green colour, from the "aboutness" of the formula represented by a picture (SUN, MOON etc.)

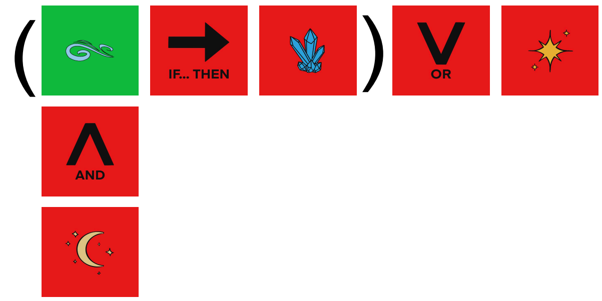


**Figure 6: A configuration displaying $(p \to q) \lor r$ horizontally and $p \land s$ vertically, both under a valuation where $p$ is true and all other atoms are false.**

- The negation symbol posed a challenge in board design; ultimately, it was omitted to maintain simple tile placement rules, though it remains present in *Tautoblocks* and *Deducto*.
- Earlier versions included additional mechanics, such as character cards with special abilities, but these were removed to simplify game-play while preserving educational effectiveness.
- Board inclusion: Initially, tiles were placed freely on a tabletop, but the introduction of a structured game board significantly improved organization and readability.

By leaving certain game rules deliberately open to modification, we embrace half-baked game design, allowing educators and students to refine rules based on their classroom needs. This adaptability encourages learning through game modding, reinforcing logical reasoning while fostering creativity.

*4.2.2* ¬SCR∧BL *Mechanics.* Each turn begins with a player drawing a tile at random. The challenge lies in placing the tiles on the board adjacent to each other to construct valid logical formulas. Adhering to specific rules is key: Atoms and connectives must alternate in the formula sequence, e.g., atom-connective-atom (Figure 2). Parentheses can be freely added, allowing players to craft complex formulas and showcase their strategic thinking (see Figure 6). To emphasize the role of logical connectives as truth-functions over their specific content or "aboutness" (see Learning Goal (5)), in *¬SCR∧BL* the pictorial representations on tiles should be ignored (see (see Figure 7), and players should focus only on the colour of the drawn tiles when deciding where to place them (note that this special rule only applies to *¬SCR∧BL*).

To keep the game dynamic, players draw challenge cards that specify tasks. These tasks range from tutorial challenges to constructing specific (complex) formulas. Successfully completing a challenge rewards players with extra points, but failure to complete a challenge results in penalties, keeping everyone on their toes.

Points are awarded based on the complexity and accuracy of formulas: Simple formulas (made up of three tiles) earn a +1 point. Complex formulas (linked or multilayered formulas) earn +2 points. However, the stakes are high: Players receive a -1 point penalty for incomplete formulas or uncompleted challenges.The ultimate objective is to climb the ranks and claim the title of the highest-ranking team of players!


**Figure 7: An illegal configuration in *Tautoblocks*, where formulas must not contain the same atom with different truth values.**

# 5 *Tautoblocks*

## 5.1 Formulating Learning goals

Specific learning objectives of the board game *Tautoblocks* include:

(1) **Introducing the Classical Negation Symbol**: the game should teach students how negation operates in formal logic, emphasizing its role as the only classical unary operator. Through game-play, students should learn that negation flips the truth-value of a proposition, and they develop an intuitive understanding of narrow vs wide scope negation.
(2) **The Role of Content (Aboutness):** While formal logic abstracts away from meaning, logical inferences in real-world contexts often depend on content-specific constraints. In particular, students should learn that an atomic proposition cannot be both true and false in the same situation.
(3) **Understanding Tautologies and Contradictions:** The game should introduce the notion of a tautology – a formula that is always true, regardless of the truth-values of its individual components, and contradiction – a formula that is always false regardless of the truth-values of its individual components

Specific game-play and pedagogical goals of *Tautoblocks* include:

- **Challenging Advanced Logic Learners:** *Tautoblocks* is designed for students who have mastered the basics of propositional logic. It introduces negation, tautologies, and contradictions, requiring players to engage with more complex logical reasoning and apply truth-functional rules strategically
- **Competitive Play:** Unlike the cooperative format of ¬*SCR*∧*BL*, *Tautoblocks* introduces individual scoring and strategic tile placement, encouraging players to compete by constructing valid and complex formulas. The competitive element enhances engagement and mirrors real-world logic applications in programming, AI, and formal reasoning.

## 5.2 Co-desinging Rules for *Tautoblocks*

*Tautoblocks* evolved from ¬*SCR*∧*BL* through an iterative design process aimed at differentiating the two games and catering to more advanced learners. During co-design sessions with students and educators, we decided to keep ¬*SCR*∧*BL* beginner-friendly while introducing a separate game that incorporates negation, tautologies, and contradictions. Additionally, a competitive element was added to maintain engagement for players who had already mastered truth tables and basic logic operators.

One of the key changes in *Tautoblocks* was the introduction of the negation symbol (¬). Unlike atoms and connectives, which are colour-coded to represent truth values, negation is neutral and serves to invert the color of the adjacent atom or formula. Co-design sessions highlighted the need for clear directionality, leading to the rule that negation only operates from left to right (when placed to the left of an atom) or from top to bottom (when placed above it).

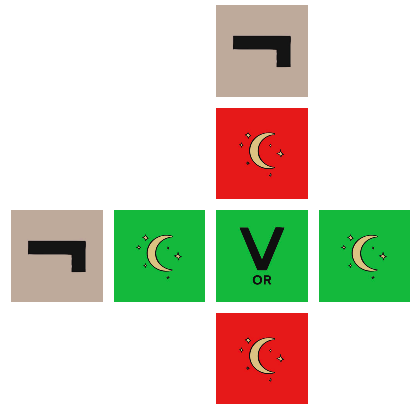


**Figure 8: Example of a configuration representing the tautology $\neg p \vee p$ in *Tautoblocks***

Another major rule change involved the placement of atoms. In ¬SCR∧BL, players could place both red and green versions of the same atom on a single line. However, in *Tautoblocks*, this is forbidden to reinforce the logical principle that a proposition cannot be both true and false in the same situation (see Figure 7). Here, each line on the board represents a single possible situation, meaning that contradictions must be avoided within a row or column.

To further challenge players, a special rule was introduced for constructing tautologies and contradictions (see Figure 8). Players who successfully build these structures earn additional points, incentivizing deeper strategic thinking about logical equivalences.

Finally, playtesting and co-design sessions led to the creation of an advanced challenge deck, which provides step-by-step tutorials on constructing logical formulas using negation, tautologies, and contradictions. This gradual introduction of complexity ensures that players can progressively engage with formal logic while still enjoying a dynamic and competitive game environment.

# 6 *Deducto*

As the third board game in the *LogiCraft* framework, *Deducto* builds on the foundation established in ¬*SCR*∧*BL* and *Tautoblocks*, introducing a new layer of logical reasoning centered on translation and deduction.

## 6.1 Formulating learning goals

Unlike the previous games, which focus on constructing formulas and manipulating truth values, *Deducto* is designed to develop translation skills, model-based reasoning, and problem-solving through puzzle-based game-play.

(1) **Learning to translate natural language into propositional logic:** Throughout the game, translation tasks are embedded into the core mechanics, requiring players to convert English sentences into logical formulas. This skill is critical for applying

logic in practical contexts, such as programming, argument analysis, and AI reasoning, where symbolic representations of statements are essential. The game provides a structured yet engaging way for students to internalize logical notation and improve their ability to work with formal representations of meaning.

(2) **Developing an understanding of logical models:** In *Deducto*, each game scenario represents a self-contained possible situation where all translated sentences within a puzzle are considered true. This reinforces the notion of models in formal logic, where truth values must be consistently assigned across all formulas. Players engage in active deduction, marking neutrally coloured sentences as true or false using color-coded tiles. This process mirrors the way logicians evaluate statements within a given model, making the abstract concept of model more tangible and intuitive.

*6.1.1 Game-play Goals of* Deducto*.* Unlike ¬*SCR*∧*BL*, which focuses on constructing formulas, and *Tautoblocks*, which emphasizes competitive play, *Deducto* is designed around *cooperative* puzzle-solving and logical deduction. The game encourages:

- **Cooperation:** Players work together to translate sentences, assign truth values, and make logical deductions within each scenario. The collaborative nature of the game fosters peer learning and discussion, helping students articulate their reasoning and refine their logical thinking.
- **Solving Puzzles and Making Deductions:** The game is structured around narrative-driven puzzles, where players must logically analyze clues, infer missing information, and determine the truth values of statements. This aspect of game-play aligns closely with real-world problem-solving in logic-based disciplines, from law and philosophy to artificial intelligence.
- **Real-World Scenarios (Narratives)**: Each puzzle is embedded in a thematic setting, such as solving a mystery, deciphering a coded message, or making strategic decisions in a simulated environment. This narrative element helps contextualize logical reasoning, showing students how logic applies to everyday decision-making and professional fields.

Through *Deducto*, students not only strengthen their grasp of propositional logic but also develop translational and deductive skills essential for advanced mathematical reasoning, computational logic, and formal analysis. The cooperative and puzzle-driven nature of the game complements the competitive and formula-building focus of the first two games, creating a well-rounded framework for learning logic through play.

## 6.2 Co-designing Rules for *Deducto*

*Deducto* evolved out of a clear need for a game that emphasizes complex translations, negation, and deductive reasoning—concepts that were either simplified or excluded in ¬*SCR*∧*BL* due to the complexities of integrating negation and color-based truth values. Through iterative co-design sessions with students and teachers, we identified key areas where existing game-play could be expanded to provide a richer logical learning experience.

A major design decision was to use neutral tiles rather than pre-assigned red or green ones. Unlike ¬*SCR*∧*BL* and *Tautoblocks*, where players directly manipulate color-coded atoms, *Deducto* introduces a reverse-engineering approach to logic. Players do not know the truth values of atoms in advance; instead, they must deduce them collaboratively, using logic pies, inference rules, and previous translations. This design shift reinforces the notion that truth values are not arbitrarily assigned to sentences but must be inferred based on logical structure and consistency within a model.

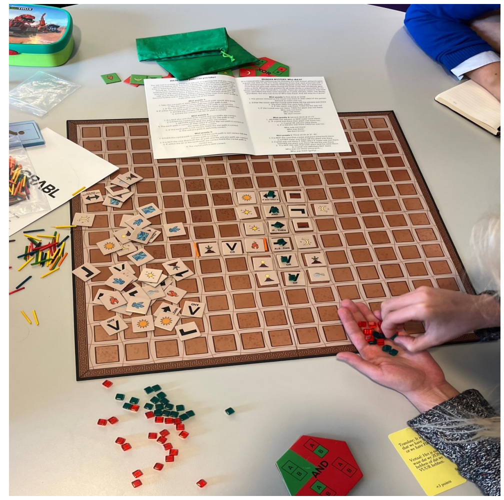

**Figure 9: Playing *Deducto* at Hyperion Lyceum**

Another key aspect that emerged through co-design was the stronger connection to real-world contexts. While ¬*SCR*∧*BL* and *Tautoblocks* abstract logical formulas from meaning, *Deducto* embraces the "aboutness" of atoms—each logical statement is embedded in a narrative-driven puzzle, giving students a compelling reason to engage with translations and deductions. This design element makes logic feel less detached from and more applicable to real-world reasoning tasks, such as detective work, philosophy, strategic decision-making, and computational problem-solving.

# 7 Playtesting sessions

## 7.1 Methods

The primary goal of our playtesting sessions was to evaluate the viability of *LogiCraft* and its three games in real classroom settings. More specifically, we wanted to find out whether the games effectively support logic education, how well they fit within a standard lesson structure, and how students engage with them in cooperative and competitive formats.

In order to achieve this, we conducted an *observational study using a qualitative research approach*. Our method followed the co-design principles outlined earlier, involving students, teachers, and university researchers in the iterative refinement of the games. During playtests, we closely observed how players interacted with the games' mechanics, how quickly they grasped the rules, and whether or not the intended learning outcomes were met.

In addition, we collected feedback on aspects such as difficulty of the game, clarity of instructions, and accessibility features. The results of these sessions included detailed observations on the game, student engagement, and how effective they were in acquiring logic concepts.

Based on these insights, we made targeted interventions to improve the games, such as refining challenge decks, adjusting game mechanics for clarity, and enhancing accessibility for colourblind players. These refinements were then incorporated into later iterations of the games to ensure they remained educational and engaging.

## 7.2 Setup

Playtesting was conducted with different target groups, including logic teachers, bachelor-level logic students, and high school students aged 11-14 at different levels of proficiency. Participants were asked to watch our game demo videos in advance to familiarise themselves with the game-play.

During the 45-minute sessions, two instructors (both logic teachers) guided participants step by step explaining the role of tiles and logic pies, and how they should be used in game-play. Playtesting began with simple tutorial challenges to introduce core concepts and mechanics before allowing students to engage in free play. Whereas logic teachers tested the competitive version of the game, younger participants played in a cooperative mode.

At the Hyperion Lyceum Amsterdam, we tested students in their first, second, and third years of logic and argumentation. After a brief 15-minute introduction to elements of the board game, most students demonstrated a sufficiently clear understanding of the rules, learning how to build structures and score points. Once players were comfortable with the mechanics, they played independently, and we observed how they interacted with the game.

For playtesting with university students at AUC and VU, we began with a Tabletop Simulator demonstration, presenting the game mechanics to the entire room while prompting discussion and questions (see Fig. 10)[1]. Once students showed an understanding of the rules, we divided them into groups to play on physical board games. This method proved effective for quickly familiarizing players with the mechanics, allowing them to transition smoothly from passive observation to active engagement.

Through playtesting sessions with around 50 students from Hyperion Lyceum, 10 students from Amsterdam University College, 8 from Vrije Universiteit Amsterdam, and 12 logic teachers from two universities, we gathered qualitative data through direct observation and post-game surveys. This feedback helped refine the games and evaluate how effectively they reinforce key logical concepts.

## 7.3 Findings from Playtesting

*7.3.1 ¬SCR∧BL: Accessibility and Engagement for Beginners.* Playtesting established that *¬SCR∧BL* is highly accessible to beginners, offering an intuitive introduction to truth tables, logical connectives, and formula construction. The use of logic pies was particularly effective, helping students grasp the meaning of logical operators through a visual and tangible approach. The cooperative nature of the game encouraged group interaction and peer learning, making it a valuable classroom tool.

[1]Readers can access the Tabletop Simulator version of our three games via these links https://steamcommunity.com/sharedfiles/filedetails/?id=3376922817 (*¬SCR∧BL*), https://steamcommunity.com/sharedfiles/filedetails/?id=3376924634 (*Tautoblocks*), https://steamcommunity.com/sharedfiles/filedetails/?id=3376925706 (*Deducto*)

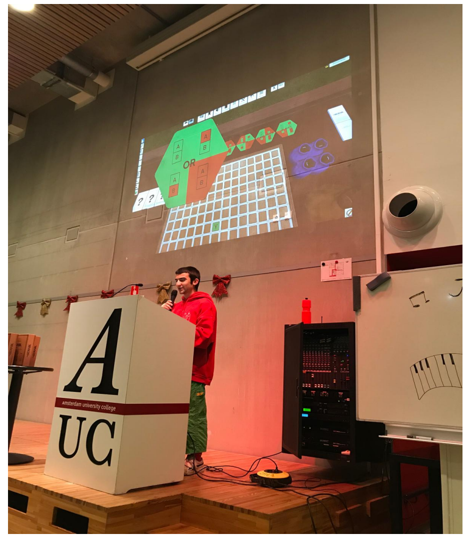


**Figure 10: Playtesting session at Amsterdam University College with the initial demonstration on the Tabletop Simulator**

One challenge observed during playtesting was that some younger students naturally interpreted the pictorial elements on tiles as being relevant to the game-play. However, the instructors clarified that *¬SCR∧BL* is purely about truth values represented by red and green rather than the content of tiles (which becomes important in other games). This shift in understanding, and a possibility to detach the meaning of colour from the symbolic representation, reinforced the distinction between different levels of semantics in logic (i.e., truth-values and "aboutness").

To further support new learners, we introduced a new deck of tutorial challenge cards based on our teaching exercises during playtesting. These "playground" challenge introduce tile placement and formula construction step by step, familiarise players with logic pies and their role in determining truth values, thus allowing beginners to build confidence before engaging in full game-play.

Additionally, accessibility concerns were addressed by adding binary markers to help colourblind players distinguish between truth values.

*7.3.2 Tautoblocks: Increased Strategy and Competitive Play. Tautoblocks* was tested with university students and logic teachers, who enjoyed its faster pace and strategic depth. Unlike *¬SCR∧BL*, which is cooperative, *Tautoblocks* introduces competitive game-play, requiring players to plan moves carefully while managing hidden tiles. The Scrabble-like mechanic, where each player holds five tiles and places up to three per turn, adds an element of long-term strategy absent in the first game.

Players found that negation, tautologies, and contradictions introduced a new layer of complexity, making the game well suited for advanced learners. The rule preventing the placement of red and green versions of the same atom on a single line reinforced the principle that a statement cannot be both true and false in the same world or model.

One challenge was that constructing tautologies and contradictions took multiple turns, requiring players to collect specific tiles.

Nevertheless, the high point rewards encouraged strategic planning, making the challenge engaging rather than frustrating.

*7.3.3 Deducto: Collaborative Deduction and Logical Reasoning.* *Deducto* is the newest addition to the *LogiCraft* framework and has undergone limited playtesting compared to the other two games. However, preliminary sessions with several more advanced students at the Hyperion Lyceum provided valuable insights. Students found the team-based deduction mechanics engaging, enjoying the challenge of working together to assign truth values and solve interconnected puzzles. The game seems to be especially appealing to students who enjoy more narrative, real-world challenges. Unlike the previous two games, *Deducto* does not focus on building formulas with tiles. Instead, players must translate natural language statements into propositional logic and deduce truth values within a model.

During testing, students and teachers highlighted the need to have solution sheets to verify their reasoning. In response, we included puzzle solutions in the final version of the game, ensuring that players can check their answers and learn from mistakes. Although *Deducto* is still in its early testing phase, initial feedback suggests that it successfully bridges formal logic with real-world reasoning, making logic less abstract and more applicable to real-life problem-solving.

## 7.4 Future Playtesting

Playtesting sessions done to date suggested that each game in the *LogiCraft* framework successfully reinforces propositional logic skills whilst catering to different learning needs:

- *¬SCR∧BL* provides a beginner-friendly, cooperative experience, ideal for introducing beginners to truth tables and formula-building.
- *Tautoblocks* increases complexity by adding negation, tautologies and contradictions, and competition, appealing to more advanced players.
- *Deducto* shifts the focus from building formulas to reasoning about models and natural language translation, reinforcing logic's real-world applications.

Thus, each game builds on the previous one, offering a progressive, hands-on learning journey. Still, despite these promising results, more rigorous testing is needed to further validate the educational impact of the *LogiCraft* framework. One of our next steps is to conduct a controlled A/B testing study, directly comparing how students learn logic through traditional methods versus through our board games. This will provide empirical data on the effectiveness of game-based learning for logic education.

In addition, we plan to expand our playtesting to a wider range of high schools, particularly those that teach mathematics, philosophy, and computer science, to assess how the games function in different educational contexts.

Although we have already gathered survey data from 50 students at the Hyperion Lyceum, which indicate that they found the game more engaging than regular logic classes, this feedback arrived after our initial review phase. A more thorough quantitative and qualitative analysis of student learning outcomes is needed in future studies.

Apart from further playtesting, we also plan to explore in which way the *LogiCraft* framework can be adapted to other areas of logic and philosophy. In collaboration with philosophy and logic colleagues at the Vrije Universiteit Amsterdam, we aim to modify the game to evaluate logic rules relative to different philosophical frameworks. This expansion would allow us to explore more advanced logical reasoning, bridging formal logic with broader epistemological, metaphysical and argumentative contexts.

Ultimately, our goal is to continue with playtesting and with refining the *LogiCraft* framework, making sure that game-based learning becomes an integral tool for teaching logic across different disciplines and educational levels.

# 8 Discussion: Costs, Benefits, and Challenges

The *LogiCraft* framework introduces a novel, game-based approach to teaching logic, offering numerous advantages over traditional instruction while also presenting certain challenges. By embedding logic learning into interactive gameplay, the games aim to improve engagement, comprehension, and retention of formal logic concepts. Nonetheless, as with any educational innovation, there are costs and limitations that must be addressed to ensure its effectiveness in diverse learning environments.

One of the key benefits of *LogiCraft* is its ability to make logic more accessible and engaging. Traditional logic courses often rely on abstract notation and repetitive exercises that can be difficult for students to connect with. Through hands-on game-play, *LogiCraft* encourages active learning and problem-solving, helping students internalise logical principles in a structured but playful way. Additionally, the progressive structure of the three games allows students to build on prior knowledge, moving from basic logical operations in *¬SCR∧BL* to more advanced reasoning in *Tautoblocks* and *Deducto*. This approach provides a clear learning trajectory, making sure that students develop basic understanding of truth calculus before tackling more complex concepts.

Another significant advantage of the framework is its emphasis on collaborative learning. Many logic courses focus on individual problem-solving, limiting opportunities for teamwork and discussion. By contrast, *LogiCraft* incorporates cooperative and competitive elements that actively encourage peer interaction.*¬SCR∧BL* supports teamwork by requiring players to collaboratively construct logical formulas, while *Tautoblocks* introduces competitive play, stimulating strategic thinking and long-term planning. *Deducto* reinforces collaborative deduction, mirroring how logic is used in real-world scenarios as part of programming, philosophy, and AI research. These varied approaches accommodate different learning styles, making the games appealing to a broad range of students.

Despite these benefits, the framework does present several challenges. One concern is alignment with traditional logic curricula. *¬SCR∧BL*, for example, integrates syntax and semantics in a way that differs from conventional classroom instruction, where these elements are often treated separately. Some students initially struggled with this approach, especially those already familiar with standard logic notation. Additional tutorial exercises may be necessary to help bridge the gap between the game and conventional teaching methods.

The learning curve for the more advanced games is another point to take into consideration. While ¬*SCR*∧*BL* is highly accessible, *Tautoblocks* and *Deducto* introduce more complex game mechanics, requiring players to engage in strategic thinking, long-term planning, and logical translation tasks. Some students found these elements challenging, suggesting that additional instructional support or gradual learning mechanisms may be needed to ensure all players can fully participate.

Classroom implementation also poses logistical challenges. Although the games are designed to fit within standard class periods, teachers must allocate time to introduce rules, facilitate game-play, and integrate the games into their lesson plans. One thing we found helpful is to conduct the initial instruction to the whole class via Tabletop Simulator.

Ensuring accessibility for all students remains an ongoing concern, particularly for those with colour vision deficiencies. The recent addition of binary markers has addressed this issue to some extent, but further refinements may be needed to enhance accessibility. In the next edition we plan to introduce more neutral, colourblind-friendly contrasts.

One of the most pressing issues for future development is empirical validation. Although initial feedback from students and teachers has been generally positive, particularly in surveys conducted at the Hyperion Lyceum in Amsterdam, more systematic studies are needed to measure the effectiveness of the games. Future playtesting will include controlled studies comparing *LogiCraft*-based instruction with traditional teaching methods to assess differences in engagement, comprehension, and retention. Additionally, expanding playtesting to more high schools that teach mathematics, philosophy, and computer science will provide a broader dataset to refine and optimize the framework.

Looking ahead, *LogiCraft* offers considerable potential for expansion. Future iterations may include digital adaptations to facilitate automated feedback and track learning progress. Additional game variations could introduce new logical frameworks, such as predicate logic or modal logic, allowing students to engage with more advanced reasoning tasks. There is also an opportunity to adapt the framework for philosophical logic, evaluating rules within different philosophical perspectives in collaboration with researchers at the Vrije Universiteit Amsterdam.

Overall, *LogiCraft* successfully addresses many of the challenges associated with traditional logic instruction by making learning interactive, collaborative, and engaging, especially for younger students. However, the framework requires further refinement to ensure alignment with existing curricula, accessibility for all learners, and implementability in different educational settings. By systematically addressing these challenges through continued playtesting and empirical research, *LogiCraft* can become a valuable tool for teaching logic in both secondary and higher education.

# 9 Conclusions

Our framework has suggested the potential of game-based learning to transform the teaching of propositional logic, making it more accessible, engaging, and relevant for students. Through the iterative design and playtesting of ¬*SCR*∧*BL*, *Tautoblocks* and *Deducto*, we have developed tools that not only teach the foundational concepts of logic but also foster compulational thinking, collaboration, and problem-solving skills. By integrating logic's syntax and semantics into interactive gameplay, these games provide an innovative alternative to traditional logic instruction, addressing many of its challenges, such as abstraction, lack of engagement, and minimal opportunities for collaborative learning. Feedback from playtesting sessions has been overwhelmingly positive, with educators and students alike expressing enthusiasm for the games' educational value and potential classroom applications. Ultimately, our goal is to integrate these games into the broader educational landscape, making logic an essential and enjoyable part of curricula across disciplines such as mathematics, programming, and philosophy.

## 9.1 Future Work

*LogiCraft* is currently still an analogue game-modification framework [20]. In future work, we aim to refine and expand the games' educational potential by means of digital representations [3].

*9.1.1 Empirical Studies.* For evaluating the games' educational impact, conducting large-scale empirical studies is critical. A key challenge is automating data collection and analysis. A digital app could serve as a valuable tool for recording gameplay data, such as response times, puzzle completion rates, and error patterns. Such data could be anonymized and used to evaluate learning outcomes longitudinally, while ensuring learner privacy. Comparative studies involving user and control groups will help determine whether the games provide measurable improvements over traditional methods.

*9.1.2 Procedural Puzzle Generation.* Another challenge is adapting logic games to personalized learning goals. For example, learners' progress could be tracked using formalized objectives, such as specific logical operators mastered or accurate applications in individual puzzles. A digital app could generate custom exercises tailored to learners' strengths and weaknesses, dynamically increasing difficulty to align with individual progress [32].

*9.1.3 Game Design for Game-Based Learning.* Exploring alternative rules and mechanics for logic games in a systematic way could enhance engagement and learning outcomes. For instance, adaptable rules could allow for different play styles or levels of complexity, making the games accessible to a broader audience [30]. Ideally, the rules themselves could be expressed using logic, enabling players to engage with meta-level reasoning about the game's mechanics [30]. This approach could lead to innovative designs that enrich the educational experience.

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