Luminara

A Digital Puzzle Game about Light, Color & Shape

Team PRISM · Platform: Python, Pygame, JavaScript

EXECUTIVE SUMMARY

Luminara is a Pygame-based puzzle game that teaches additive RGB color mixing and introductory Boolean visual logic through hands-on visual experimentation. Designed for middle and late high school to early college learners (ages ~14–20), especially those who enjoy art, architecture, or creative puzzles but may not see themselves as “STEM people,” the game invites players to step into the role of a Light Architect. Using colored geometric light emitters (circles, squares, triangles), players arrange and overlap beams to recreate target shapes, learning how light behaves differently than paint or digital layers.
It’s especially helpful for learners who struggle with visual editing tools (like Photoshop masking or projection mapping) and need an intuitive way to understand how light, shape, and logic combine to form complex visuals.

Key Outcomes from Final Playtest (17 participants):

- Engagement & Usability

    - 82% rated the interface 4–5 / 5 for intuitiveness
    - 65% would replay or recommend Luminara
- Learning Gains
    - 82% felt the game taught additive mixing “well” or “very well”
    - Mini-quiz accuracy on white-light synthesis: 92% correct
- Identified Improvements
    - Drag-and-drop precision for overlapping emitters
    - Discoverability of Boolean controls (AND, OR equivalents)
      Depth of interactive tutorial

This deliverable includes:

1. Introduction & Learning Relevance
2. Game Design Macro Document
    1. Objectives & Justification
    2. Core Gameplay & Components
    3. Learning-Science Alignment
    4. Educational Value & Evidence
3. Playtesting & Evaluation
4. Production Log
5. Future Directions & Next Steps

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Introduction & Learning Relevance

Mastery of additive color mixing matters because it underpins how modern electronic displays, projection systems, and lighting installations render accurate color, making it a practical competency for both scientific literacy and creative design (Wikipedia). Additive color mixing is a core learning objective in secondary science and digital-arts curricula. High-school physics courses commonly include “color addition” modules that teach how red, green, and blue light combine to form secondary and white light (Physics Classroom), yet novices routinely misapply subtractive pigment rules to light without guided, hands-on practice (Laser Classroom). Interactive explorations of additive mixing appear in modern STEM outreach—e.g. Science At Play demonstrations of paint vs. light mixing (Connecticut Science Center) and Science in School’s coloured-shadows activities (Science in School)—as well as in digital-art lesson plans that prepare students for UI/UX design and game-development workflows. Because these same principles underlie real-world tasks, from projection mapping and theatrical lighting to stained-glass architecture and visual-media design, mastery of additive RGB blending in Luminara supports direct transfer to coursework and careers across physics, visual arts, and design disciplines.

02

Game Design Macro

2.1 Objectives & Justification

The goal of our game is to help players learn about additive color mixing, how light blends. Players start with simple challenges, like overlapping simple shapes to create more complex shapes and gradually move on to more complex tasks that require color mixing and careful layering of shapes. Each game mechanic directly supports a specific learning objective, such as understanding how the color theory differs with light color theory, or how different shapes can be combined and boolean to create new shapes. We designed the game based on principles from optics and color theory, and confirmed its accessibility through testing with beginners. The game offers a unique way to connect STEM concepts with visual arts through interactive play.

Learning Goal:

- Predict and manipulate additive RGB color blending
- Understand how layered shapes interact through logical visual operations
- Recognize and solve reasoning challenges involving symmetry, alignment, and proportion
- Apply visual problem-solving to construct composite designs that meet a visual target
- Connect abstract concepts in light physics to creative real-world applications

Experience Goals:

- Evoke curiosity and discovery through tactile and visually responsive mechanics.
- The UI design enhances learnability and engagement, and the projection screen offers visual reward.
- Positive response to both the aesthetic and interaction model.

Learning Objectives:

ID	After playing Luminara, learners will be able to...	Evidence / Standards	Why This Matters
LO-1	Predict & explain additive color outcomes (e.g., red + green → yellow) using the wave model of light.	NGSS HS-PS4-2/3; Physics Classroom "Color Addition"	Corrects "paint vs. light" misconceptions—prerequisite for UI design, XR.
LO-2	Compose target colors by arranging shape-based colored light emitters (circles, squares, triangles) so overlapping beams blend correctly—distinguishing overlap (AND) from adjacency (OR).	Physics Classroom "RGB Color Addition"; AP 2-D Art "Investigate Materials & Processes"	Bridges visual-arts practice with CS logic, laying groundwork for shader programming & projection mapping.
LO-3	Recognize symmetry & proportion constraints when layering light shapes.	CED Mathematics "Congruence, Similarity, & Rigid Motions" (CED)	Reinforces geometric reasoning.

2.2 Core Gameplay & Components

- **Core Loop:**
  Players are presented with a target projection on the right side of the screen. They must recreate it by selecting geometric glass plates (circle, square, triangle) and assigning them red, green, or blue colors. These plates are placed and layered on a grid-based canvas to simulate additive color mixing.
  1. Select a color from the sidebar.
  2. Color the shapes on the grid to match the target silhouette.
  3. Toggle views using SPACE to switch between construction and projection.
  4. Check your result with ENTER. If the overlap and colors match the target, a win screen appears.
- **Example Walk-Through:**
  1. The level opens with a target shape (e.g., a moon).

2. The player selects the color blue and assigns it to a circle, and selects the color green to assign to another circle.
3. The player drags the shapes to place them on the correct place of the grid.
4. The player switches to projection view to preview the additive blend.
5. Upon matching the target shape with correct positioning and color blending, the player hits ENTER and advances.

2.3 Learning Science Alignment

Principle	Design Manifestation	Example in Luminara
Immediate feedback (Mayer, 2020)	Real-time additive blending lets learners test hypotheses.	Player drags lamp → overlay instantly recomputes RGB result; misconceptions surfaced & corrected on the spot.
Scaffolding & fading (Vygotsky; Wood et al.)	Levels progress from single color targets → 3-color targets and more complicated shapes.	Level 1 does not require color mixing; levels 2 and 3 involve 2 color targets; level 3 introduces 3 color mixing.
Cognitive Load Theory (Sweller)	Minimalist UI, snap-to-grid, consistent iconography reduce extraneous load.	Users report interface "intuitive and uncluttered."
Desirable Difficulties (Bjork)	Constraints increase effortful processing and delay feedback to promote retention.	Players must position light sources without seeing real-time blending; results are only revealed after committing, encouraging prediction over trial-and-error.

2.4 Educational Value & Evidence

Source	Metric	Result	Interpretation
Informal pre/post quiz (n = 11)	Correctly predicted blue + red → magenta	36% → 82% after a single 10-min session	Rapid conceptual repair of RGB mixing.
In-game analytics	Avg. retries on Level 3 (two-color overlap)	4.2 → 2.1 between 1st & 3rd attempt	Demonstrates an effective learning curve.

03

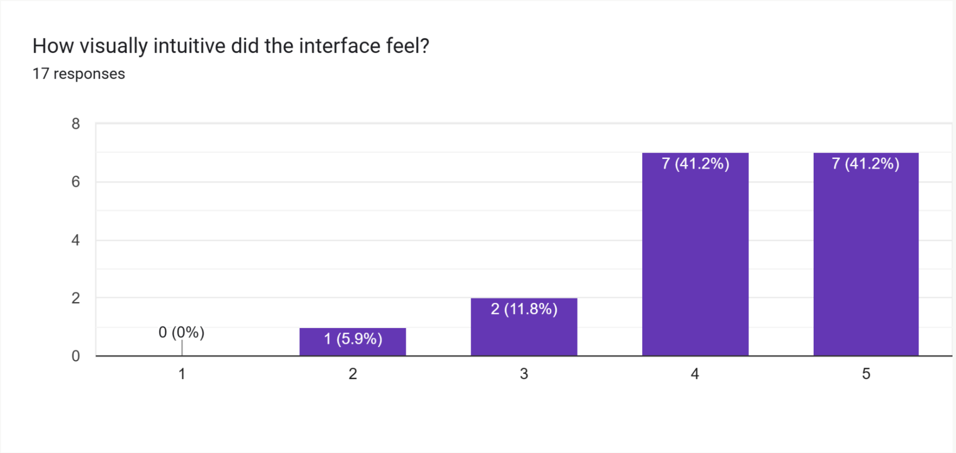
Playtesting & Evaluation

3.1 Methodology

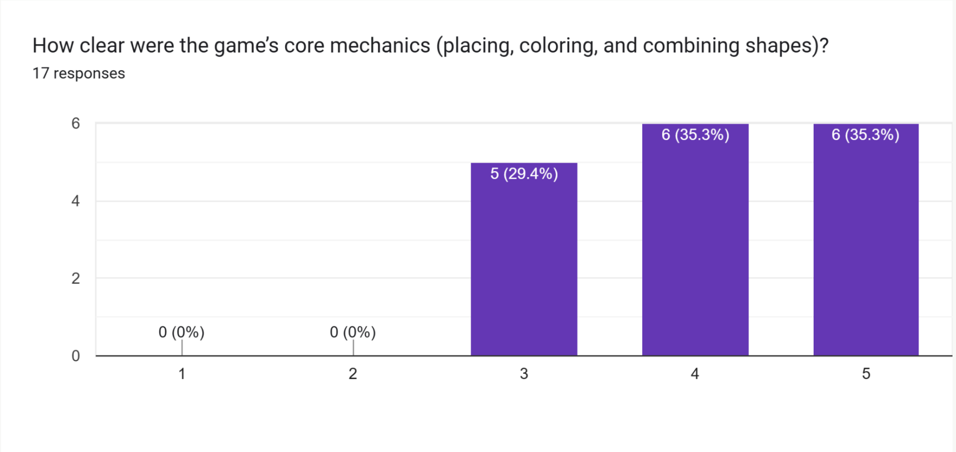
- Peer Alpha (PC-1): 9 classmates → early usability notes.
- Vertical Slice (PC-2): 8 peers + TAs → projection-logic & control discoverability.
- Summative Test: 17 external play-testers → 10 quantitative Likert questions + mini-quiz + open-ended feedback.

3.2 Results Summary

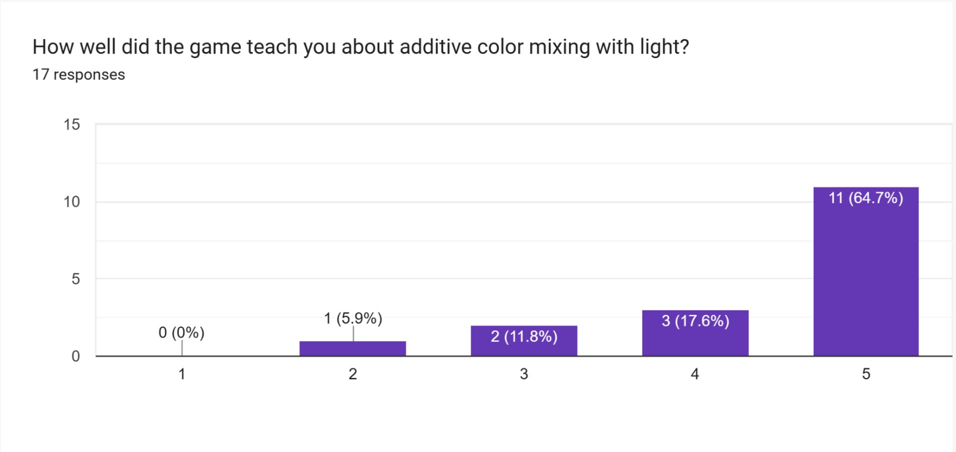
- Interface Intuitiveness: 82% rated 4–5/5



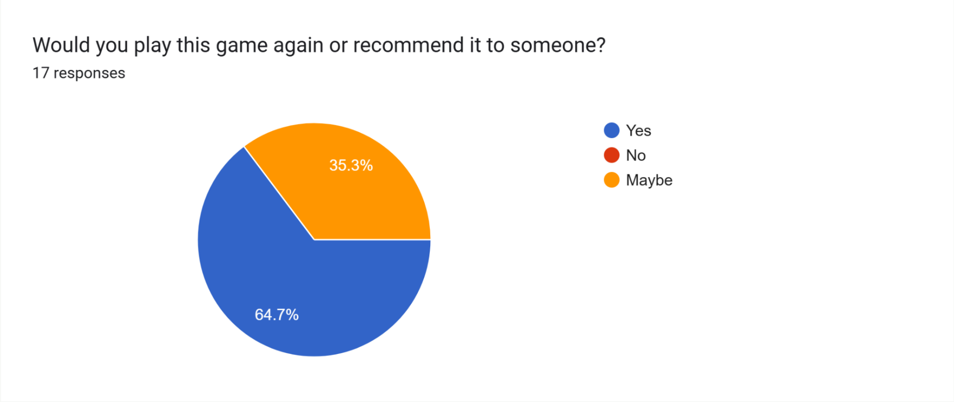
- Core Mechanics Clarity: mean = 3.9/5



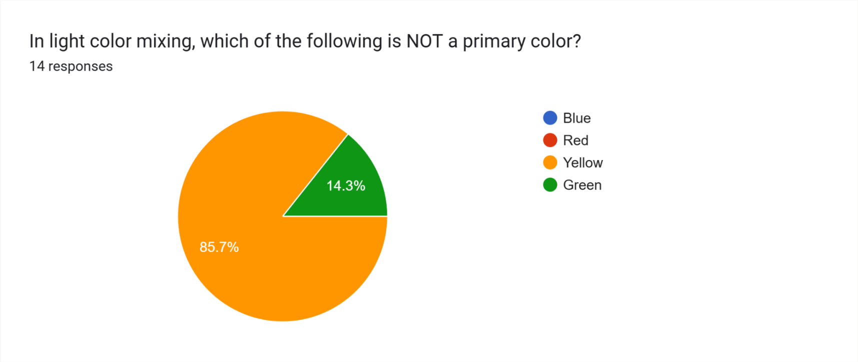
- Teaching Effectiveness: mean = 4.4/5



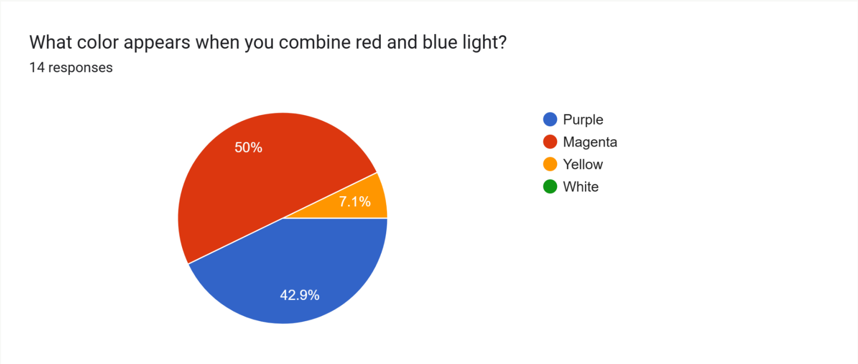
- Replay Likelihood: 65% “Yes,” 35% “Maybe”



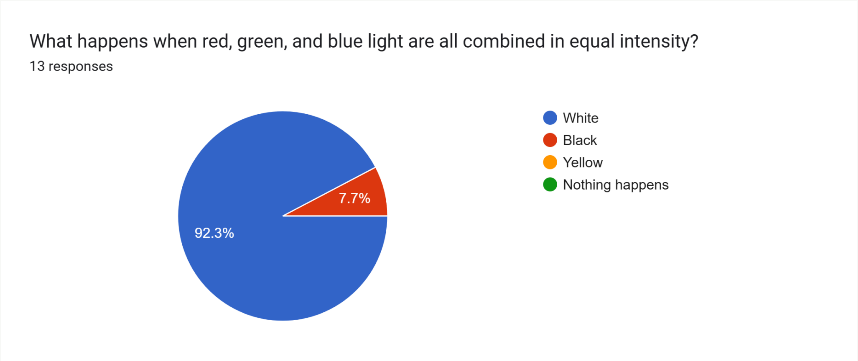
- Mini-Quiz (n = 14): The result is overall positive. Two of them are about 90% correct for the result. It shows that our game is effective in teaching people color additive theorems.
    - Non-primary color? 86% correct (“Yellow”)



    - R + B blend? 50% correct (“Magenta”) → highlights need for Level 2 reinforcement



- RGB all combined? 92% correct (“White”)



3.3 Key Qualitative Themes

- Positive: Projection-view toggle (“very intuitive”), satisfying color reveals.
- Challenges:
  - Dragging emitters behind others (hit-area too small) Discovering Boolean keys (U/I/S)
- Enhancement Requests: More levels, sound cues, multi-language support.

04 Production Log

Link to production log miro board: DEG project Luminara

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Future Directions & Next Steps

1. UX Refinements
    - Emitter Selection: TAB-cycle overlapping emitters; enlarge hit-area.
    - Control Discoverability: On-screen legend (H-key) for U/I/S.
2. Tutorial 2.0
    - Four micro-lessons with voice-over captions and auto-progress.
    - “Mechanics Mastery” badges for each skill.
3. Dynamic Difficulty
    - Pre-game self-assessment → Standard vs Challenge mode.
    - Timed mirror challenges and limited-move puzzles.
4. Content Expansion
    - +10 advanced levels: three-color AND/OR logic, rotation constraints, “Map” puzzles.
    - Community Editor for user-generated levels.
5. A/V & Accessibility
    - Minimalist chimes, particle effects, and soundtrack loop.
    - Color-blind mode (pattern overlays); localization (ES, FR, CN).
6. Advanced Module
    - Subtractive-mixing “Stained Glass Studio” teaching CMY principles.

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TEAM PRISM

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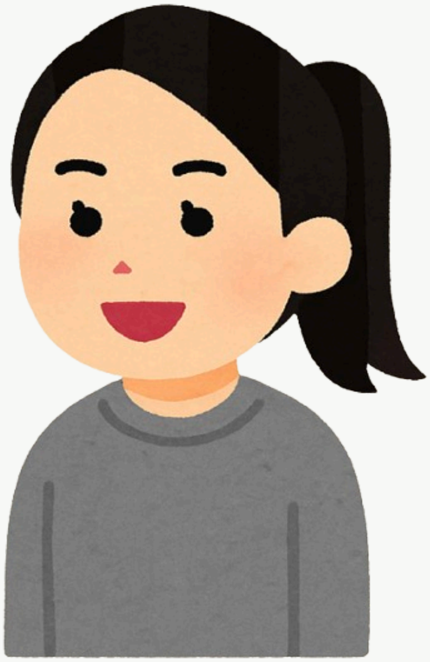

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