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Play by Design: Developing Artificial Intelligence Literacy through Game-based Learning

***Xiaoxue Du*[1*], *Xi Wang*[2]**

[1] *MIT Media Lab, MIT, Cambridge, MA, 02139, USA*
[2] *Columbia University, New York, 10025, USA*

ABSTRACT

The paper proposes an innovative approach aimed at fostering AI literacy through interactive gaming experiences. This paper designs a game-based prototype for preparing pre-service teachers to innovate teaching practices across disciplines. The simulation, Color Conquest, serves as a strategic game to encourage educators to reconsider their pedagogical practices. It allows teachers to use and develop various scenarios by customizing maps, giving students agency to engage in the complex decision-making process. Additionally, this engagement process provides teachers with an opportunity to develop students' skills in artificial intelligence literacy as students actively develop strategic thinking, problem-solving, and critical reasoning skills.

Keywords: Game-based learning; Game-based assessment; Artificial intelligence literacy; Design thinking; Computational thinking; Teacher education

1. Introduction

Understanding AI is becoming essential in today's educational landscape. It equips students with knowledge to engage with the technology that is fundamentally reshaping our world. This comprehension empowers students to make informed decisions about how they interact with AI systems, both in their personal lives and future careers. It is critical to invite students to responsibly use AI and develop their abilities to apply what they have learned in solving authentic real-world challenges [1]. Moreover, a foundational understanding of AI fosters not only computational skills but also pivotal capabilities in

*CORRESPONDING AUTHOR:
Xiaoxue Du, MIT Media Lab, MIT, Cambridge, MA, 02139, USA; Email: xiaoxued@media.mit.edu

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critical thinking and problem-solving, proving integral in navigating the increasingly dynamic technological landscape [2]. By integrating AI education into curricula, educational institutions should prepare students to be active participants in a future where AI is likely to play an even more significant role across various industries and aspects of society [3]. This ensures that they are not only consumers of AI-driven products and services but also informed contributors to the development and ethical implementation of these technologies.

At the same time, gamification provides an interactive learning experience in building the educational landscape. It not only imparts knowledge but also hones decision-making in an increasingly complex and AI-driven world. This innovative approach prepares students to not only be well-informed users of AI but also positions them as potential innovators and contributors in the field of artificial intelligence. This also allows teachers to innovative pedagogy in daily classroom teaching.

The paper proposes an innovative approach aimed at fostering AI literacy through interactive gaming experiences. By integrating AI concepts into multi-player games, participants are not only entertained but also empowered to grasp the fundamentals of AI in a practical and engaging manner. Through dynamic game-play scenarios, users navigate complex AI systems, make strategic decisions, and witness the impact of their choices. This hands-on approach not only demystifies AI but also cultivates a deeper appreciation for its potential and ethical considerations. Through Color Conquest, pre-service teachers could further develop pedagogical practice in classroom teaching.

2. Literature review

Game-based learning offers an innovative approach by infusing interactive and immersive experiences into traditional classrooms [4]. This approach captures students' attention and sustains their interest in learning within diverse simulations [5]. Through games, learners become active participants, making decisions, solving problems, and exploring complex scenarios, which leads to deeper comprehension and retention of concepts. Moreover, the experiential nature of game-based learning allows students to witness the practical implications of their studies, bridging the gap between abstract theory and real-world application [6]. Immediate feedback mechanisms and adaptive technologies provide tailored learning experiences, ensuring that students receive content at a pace aligned with their individual proficiency levels [7]. This fosters autonomy and self-directed learning, promoting a growth mindset and resilience in the face of challenges [8]. Collaborative elements within games encourage teamwork, communication, and a sense of community, enriching the learning environment. Additionally, games offer a safe space for experimentation and failure, instilling a culture of curiosity and exploration [9].

Studies have shown that using game-based learning for immersion learning enhances long-term knowledge retention, affirming its efficacy as a powerful educational tool [10]. Overall, game-based learning not only transforms education into a dynamic and engaging experience but also equips learners with critical thinking skills and a passion for lifelong learning [11].

In the field of teacher education, game-based learning provides an innovative approach as teachers could use diverse technology in classroom teaching [12]. Through interactive simulations and virtual environments, teachers could practice and refine their instructional techniques in a risk-free setting against dangerous settings in the real world [13,14]. This approach allows them to navigate various classroom scenarios, adapt to diverse student needs, and implement effective teaching strategies. By actively participating in these immersive experiences, educators develop an understanding of the complexities and nuances of teaching. Moreover, the dynamic nature of game-based learning encourages them to critically reflect on their teaching practices and make informed decisions in real time [15]. The incorporation of immediate feedback mechanisms ensures that they receive constructive input, enabling them to adjust and refine their approaches [16]. This iterative process

cultivates a growth mindset, preparing educators to adapt and innovate in the face of evolving educational landscapes. Additionally, collaborative elements within educational games simulate the teamwork and communication skills necessary for effective teaching [17]. This experiential approach not only makes the learning process more engaging and memorable but also instils in educators a deep sense of empathy and understanding for their future students [18].

Game-based learning for developing AI literacy is a growing field at the intersection of education and artificial intelligence [19]. Scholars have recognized games as immersive platforms to introduce complex AI concepts in an engaging and interactive manner. This approach capitalizes on the inherent appeal of games, which can explain abstract notions of algorithms, machine learning, and neural networks into tangible, hands-on experiences. Additionally, recent advances in technology have facilitated the creation of AI-driven educational games that simulate real-world scenarios, providing learners with a dynamic environment to experiment with AI algorithms and understand their implications in various contexts [20]. Moreover, the gamification of AI literacy serves to democratize access to this critical domain of knowledge. It allows learners of diverse backgrounds and ages to engage with complex AI concepts (e.g., decision trees) in a non-intimidating and inclusive manner. Several researchers have emphasized how multi-player environments in educational games can foster collaborative problem-solving and knowledge sharing, creating a community of learners dedicated to AI literacy. This communal aspect not only enhances comprehension but also nurtures a supportive learning environment where individuals can collectively grapple with the complexities of AI. As the demand for AI skills continues to grow across various industries, leveraging game-based learning approaches offers a promising avenue to equip a wider demographic with the foundational knowledge and critical thinking abilities necessary to navigate the evolving landscape of artificial intelligence [21].

3. Theoretical framework

Design thinking is a creative problem-solving approach that places a strong emphasis on empathy, ideation, and iterative development [22]. When applied to the realm of AI literacy, it introduces a structured framework that involves empathizing with end-users, defining problems, generating creative solutions, prototyping those solutions, and rigorously testing them. It gives students agency to engage in real-world problems and proposes solutions to solve them through a systematic process. Computational thinking is a problem-solving approach rooted in principles of computer science, aimed at dissecting intricate issues into more manageable components [23]. The benefits of integrating computational thinking into educational curricula, emphasise its role in fostering critical thinking and problem-solving skills among students [24].

The Five Big AI Ideas serve as a cornerstone in the understanding of artificial intelligence. These concepts encompass critical aspects of AI development and application [25]. The first idea, Perception, delves into enabling machines to comprehend and interpret the world, employing techniques like computer vision and natural language processing. Representation and reasoning involve instructing machines to not only hold knowledge but also make informed decisions based on that knowledge, often utilizing methods such as knowledge graphs and symbolic reasoning. Learning, the third idea, encompasses various machine learning techniques like supervised, unsupervised, and reinforcement learning, allowing machines to enhance their performance over time. Natural interaction explores the fusion of AI with physical systems, enabling machines to interact with the physical world. The fifth idea, social impact, highlights the critical demands of using AI to solve real-world problems.

In conjunction with these ideas, the AI Literacy Framework highlights the critical need to use AI responsively. It emphasizes the need for individuals to understand not only the capabilities but also the limitations and potential implications of AI. This awareness empowers people to make informed decisions

and take appropriate actions when interacting with AI systems or developing AI-based solutions. Incorporating responsible AI practices into the framework, ensures that AI is harnessed for the betterment of society while mitigating potential risks and ethical dilemmas. This approach aligns with the broader goal of promoting AI literacy as a means to navigate the evolving landscape of artificial intelligence effectively.

4. Game-based design

Design thinking is demonstrated in this game through several key aspects. Firstly, empathy plays a crucial role in the game-play as players engage in simultaneous decision-making, necessitating an understanding of their opponent's potential choices. This cultivates an empathetic perspective, a fundamental component of design thinking. Moreover, the game encourages ideation and iteration. Players are prompted to think strategically in both phases, requiring them to devise plans and adapt them in response to the changing dynamics of the board. This iterative process mirrors the cyclical nature of design thinking, emphasizing the importance of refinement and improvement. Additionally, the game adheres to a user-centred approach by preventing redundancy in choices. This design feature ensures that players are engaged in meaningful decision-making, contributing to their overarching strategic objectives. By incorporating these elements, the game embodies the principles of design thinking, promoting creative problem-solving and user-centric design.

Computational thinking principles are embedded within the mechanics of this game. Firstly, the concept of decomposition is illustrated as players systematically dissect the multifaceted task of territory claiming and connection into manageable, step-by-step actions. This mirrors the essence of computational thinking, which involves breaking down complex problems into smaller, more manageable components. Additionally, the game prompts players to engage in abstraction, compelling them to contemplate the conceptual notions of territory ownership and connection, which are visually represented on the board. Furthermore, players are challenged to think algorithmically, devising strategies for claiming territories and establishing connections. These strategies can be likened to algorithms, embodying computational thinking in practice.

Furthermore, the game encourages collaboration and community building through critical thinking, strategic planning, and adaptability, all of which are essential skills that align with the goals of AI literacy. Students should discuss their own strategies and the opponent's strategies. Students are encouraged to find the algorithm for gaining the highest score and assume the possibility of winning, and think in terms of both spatial reasoning and decision-making, which are pertinent to understanding AI concepts like perception and representation & reasoning.

5. Game-based mechanics

In the initial phase, Player 1 (Blue) and Player 2 (Green) are presented with the simultaneous task of strategically choosing an uncoloured area on the board (see Appendix). This decision-making process initiates the territorial claim, as chosen areas transition to the respective player's colour. However, in the event that both players opt for the same area, a strategic twist is introduced. The area is promptly marked in red, denoting its inaccessibility for subsequent selections (see **Figures 1 and 2**). This strategic mechanic prevents redundancy in choices, encouraging players to analyze their decisions with precision and foresight. The phase's iterative nature, defined by the parameter N set by the map creator, grants players the opportunity to strategically claim territories over multiple rounds, nurturing a dynamic environment that calls for adaptability and long-term planning(see **Figure 3**).

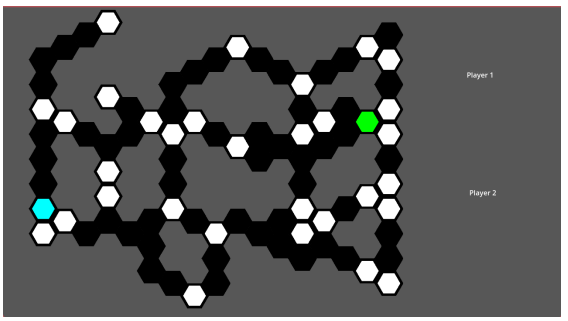

Figure 1. After two players simultaneously claim an uncoloured area on the board.

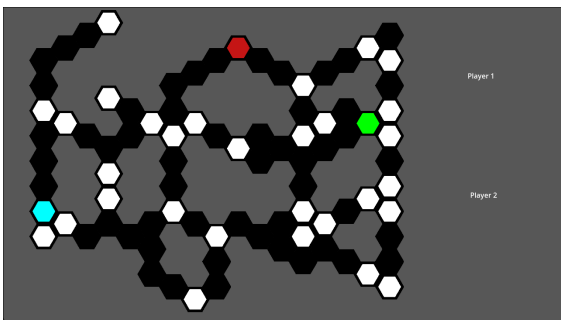

Figure 2. Once two players claim the same area.

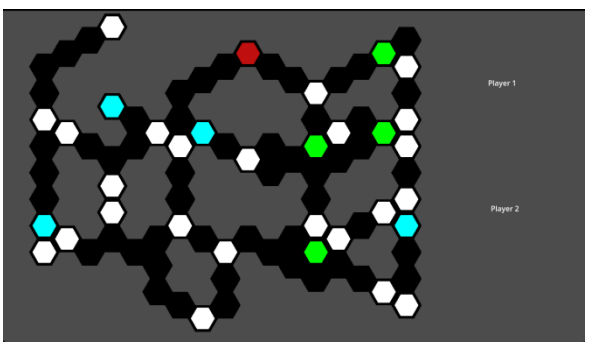

Figure 3. After N = 5 times claim area.

Transitioning into the second phase, players face the challenge of connecting two areas of their own colour with lines (see **Figure 4**). This phase introduces additional layers of complexity, as players must navigate through the board, factoring in the accessibility of black and white areas and the impassibility of red zones. Players must consider the implications of their routes while concealing their intentions from the opposing player. Once both players have successfully established their connections, the game proceeds to the scoring phase, a pivotal moment in determining the victor. The scoring system rewards strategic prowess and penalizes hasty decision-making. If the lines of the two players do not intersect, each player garners points commensurate with the length of their respective line (see **Figure 5**). Conversely, in the event of an intersection, players are prompted to strategically evaluate the length of their opponent's line (see **Figures 6 and 7**).

Furthermore, the visual cues of red markings serve as a feedback mechanism. The areas connected by players in this phase, as well as any intersection points, are distinctly marked in red. This visual representation reinforces the strategic implications of their choices.

This iterative game-play process persists until players are no longer able to connect further lines, marking the conclusion of the game. The player who emerges with the higher score attains victory, showcasing superior strategic acumen and territorial control. This culminating moment emphasizes the importance of thoughtful decision-making.

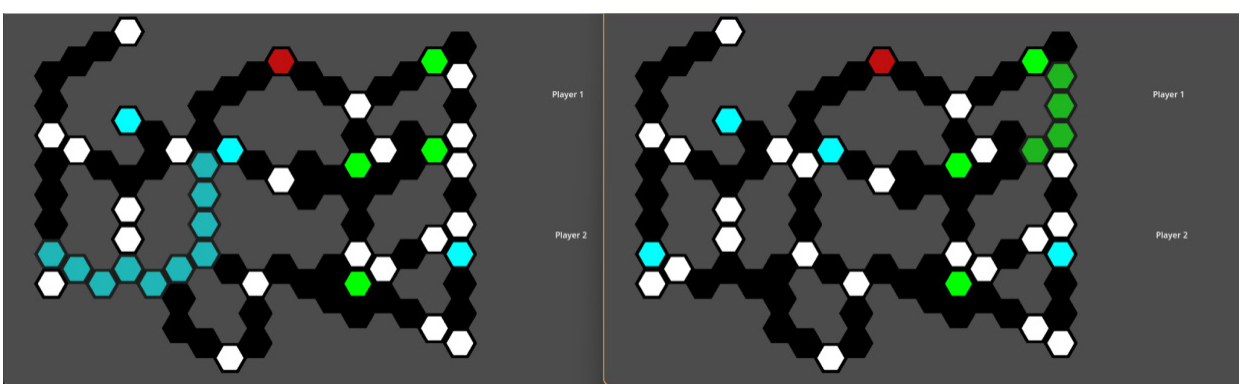

Figure 4. Two players try to connect their own colour area.

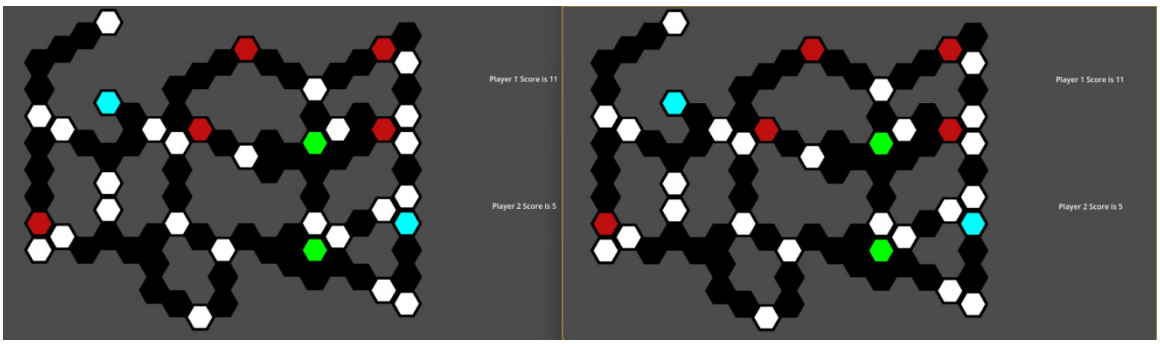

Figure 5. Players receive a score equal to their connecting range.

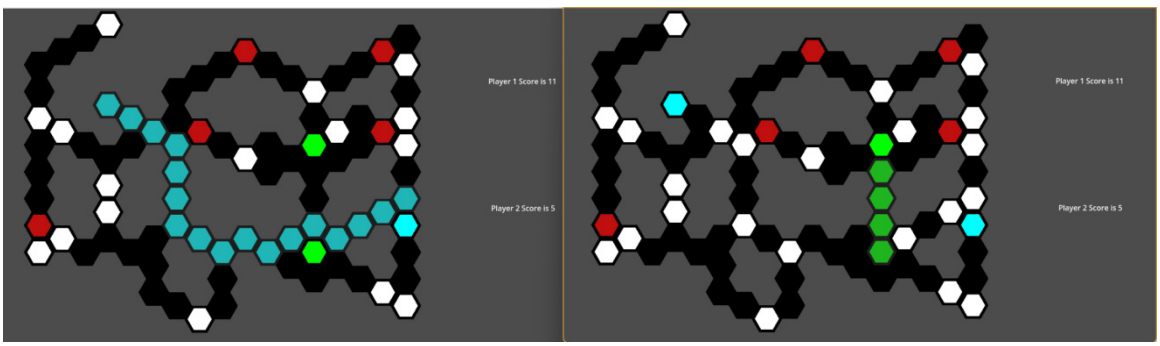

Figure 6. Players try to connect their own colour area again.

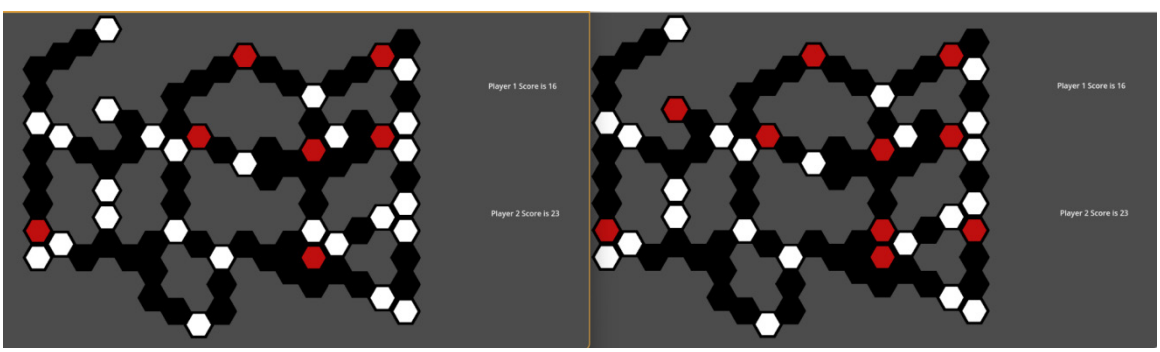

Figure 7. Players receive a score equal to their opponent's connecting range.

5.1 Customizable map design

One of the key innovations in the game is the integration of a map design feature, allowing players to take an active role in shaping their gaming experience. This feature empowers players with the ability to design their own maps, complete with uncolored areas, pathways, and potential obstacles. By providing players with creative agency, the game not only enhances engagement but also fosters strategic thinking. This customization element introduces a layer of personal investment, as players can craft environments that cater to their individual play styles and preferences (see **Figures 8-11**).

A science teacher could use the game's map design feature as a dynamic educational tool in the classroom. This innovative aspect enables students to delve into scientific concepts through interactive map creation. For instance, students might design maps representing ecosystems, complete with various biomes, habitats, and species. This hands-on activity encourages critical thinking as they strategically plan the layout and relationships within the ecosystem. Through this exercise, students gain a deeper understanding of ecological interactions, spatial relationships, and the interdependence of organisms within an ecosystem. This approach not only

makes science concepts tangible but also cultivates analytical thinking skills, providing a profound and memorable learning experience.

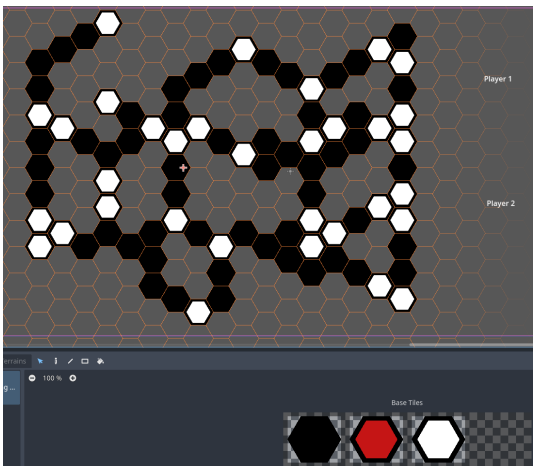

Figure 8. Customizable map design.

5.2 Community-driven interaction

The interactive aspect of map sharing amplifies the social dimension of game-play. Players can share their creations with their peers or the wider gaming community, creating an exchange of ideas and challenges. This not only builds community among players but also generates a diverse array of maps, each presenting unique challenges and strategic opportunities. Through this collective effort, the game's complexity expands exponentially, ensuring that game-play remains dynamic and engaging over time across disciplines.

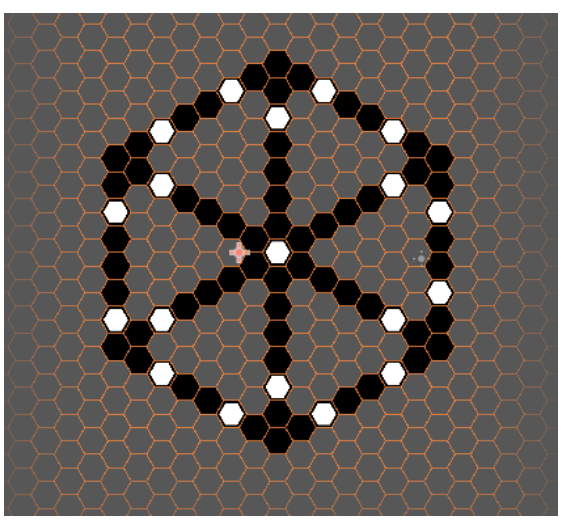

Figure 9. The idea of segregation in geometry.

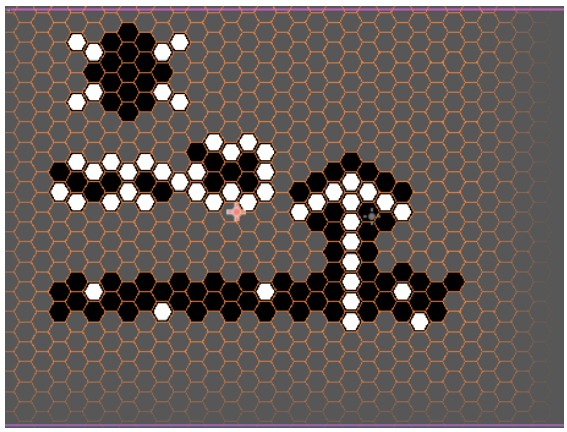

Figure 10. Analog ecosystem.

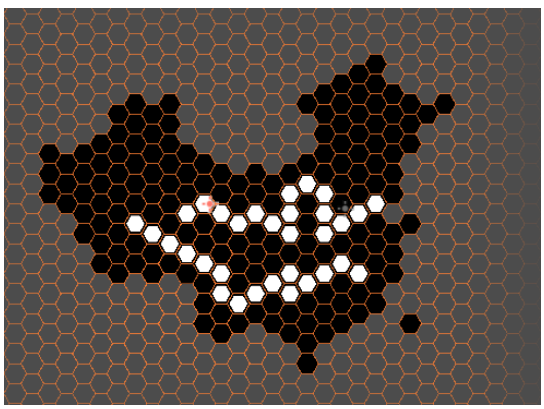

Figure 11. Analog China region with two main rivers.

5.3 Promoting creativity and collaboration

The game's map design feature encourages a culture of creativity and collaboration. Players are not only consumers of content but active creators within the game's ecosystem. This collaborative approach not only strengthens teamwork skills but also leads to the emergence of challenging maps that require collective problem-solving to conquer. Additionally, the ability to rate and provide feedback on user-generated maps helps identify high-quality designs and motivates creators to refine their work, further enriching the overall gaming experience across disciplines in classroom teaching.

6. Methods

The study involved a total of 20 pre-service teachers enrolled in a teacher education program. The primary material used in this study was the ed-

ucational game Color Conquest, designed to teach AI concepts in an interactive and gamified manner. The game incorporated elements of strategy, problem-solving, and critical thinking, all aimed at enhancing AI literacy skills. Participants completed a post survey to gather feedback on their experience with the game. The survey included Likert-scale items and open-ended questions to assess engagement, perceived learning, and overall satisfaction with the game. Quantitative data from the post-assessments was analyzed to understand the overall satisfaction rate (see **Table 1**). Qualitative data from the follow-up survey were analyzed thematically to extract key insights and feedback from participants.

7. Results

Responses from the follow-up survey provided valuable insights into participant perceptions of the Color Conquest game. Qualitative feedback highlighted the game's effectiveness in making complex AI concepts more accessible and enjoyable. A substantial majority of participants (87%) reported high levels of engagement with the "Color Conquest" game. Many expressed enthusiasm for the interactive nature of the game, noting that it provided a dynamic and immersive learning experience. A notable 92% of participants indicated that they perceived a significant increase in their understanding of AI concepts after engaging with the game. Respondents highlighted the game's ability to simplify complex topics and provide practical applications for theoretical knowledge. A significant proportion (85%) of participants expressed overall satisfaction with the "Color Conquest" game as an educational tool. Comments emphasized the game's effectiveness in making AI concepts more accessible, as well as its role in fostering a collaborative learning environment.

Several participants praised the game's feature that allowed them to customize scenarios. They appreciated having agency in their learning journey, as it enabled them to explore specific AI concepts

Table 1. Overall satisfaction questionnaire.

No.	Item
1	On a scale of 1 to 5, how would you rate your level of engagement with the "Color Conquest" game? (1 = Not Engaged at All, 5 = Highly Engaged)
2	How satisfied were you with your overall experience using the "Color Conquest" game as an educational tool? (1 = Very Dissatisfied, 5 = Very Satisfied)
3	To what extent did you feel that playing the "Color Conquest" game helped you learn and understand AI concepts?(1 = Very unhelpful, 5 = Very helpful)
4	Please rate the extent to which you feel your knowledge of AI concepts improved after playing the "Color Conquest" game. (1 = Not Improved, 5 = Significant Improvement)
5	Were you able to customize scenarios in the "Color Conquest" game to explore specific AI concepts of interest to you? (Yes / No)
6	To what extent did you feel that customized scenarios in the game helped you learn AI concepts? (1 = Very unhelpful, 5 = Very helpful)
7	How confident are you in applying the AI concepts you learned from the "Color Conquest" game in your future teaching practices in classroom teaching? (1 = Not Confident at All, 5 = Very Confident)
8	Do you believe that the "Color Conquest" game has positively influenced your long-term understanding and application of AI concepts? (Yes / No)
9	What specific aspects of the "Color Conquest" game did you find most effective in helping you grasp AI concepts?
10	Were there any challenges or areas of confusion you encountered while using the "Color Conquest" game for learning? Please describe.
11	How do you think the "Color Conquest" game could be further enhanced to provide a more engaging and educational experience for learners?
12	In what ways do you envision incorporating the knowledge gained from the "Color Conquest" game into your teaching or other professional endeavours?

of interest in greater depth. A small subset of participants suggested minor enhancements, such as incorporating additional levels or challenges to further reinforce specific AI principles. These suggestions were largely centered on expanding the depth and complexity of the game-play. A noteworthy proportion of participants expressed optimism regarding the long-term impact of the game on their AI literacy. They believed that the hands-on, gamified approach provided a solid foundation for continued learning and application in their future teaching endeavours.

8. Conclusions and future work

In conclusion, this paper presents an innovative approach to enhance AI literacy through immersive gaming. By introducing a game-based prototype, this approach provides pre-service teachers with the tools to rethink teaching strategies across diverse subjects [26]. The simulation, Color Conquest, serves as a catalyst for educators to re-evaluate their pedagogical approaches, encouraging them to create customized scenarios and giving students agency in their learning journey. Furthermore, this interactive process not only develops students' abilities in strategic thinking, problem-solving, and critical reasoning but also cultivates their proficiency in AI literacy in the 21st century.

Future work could explore the potential integration of AI-driven adaptive learning systems within gamified educational platforms to tailor content to meet individual student needs and learning styles. Also, future work could conduct assessments in evaluating students' cognitive, social and emotional learning outcomes as interacting with the games. The multivariate approach will contribute to the field of human-centered dynamic assessment in creating a student-learning environment that fosters not only academic skills but also emotional intelligence, teamwork, and problem-solving skills. This approach will advance the broader field of human-centered assessment, ultimately shaping a more dynamic and responsive learning environment for students.

Author Contributions

Both authors have made contributions to this article. Xiaoxue Du is designated as the corresponding author.

Conflict of Interest

There is no conflict of interest.

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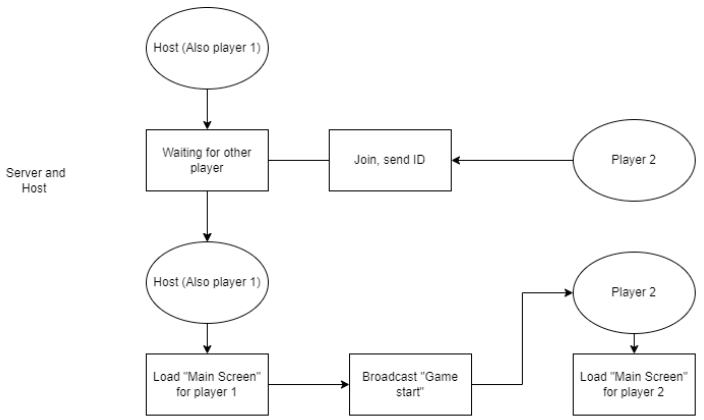
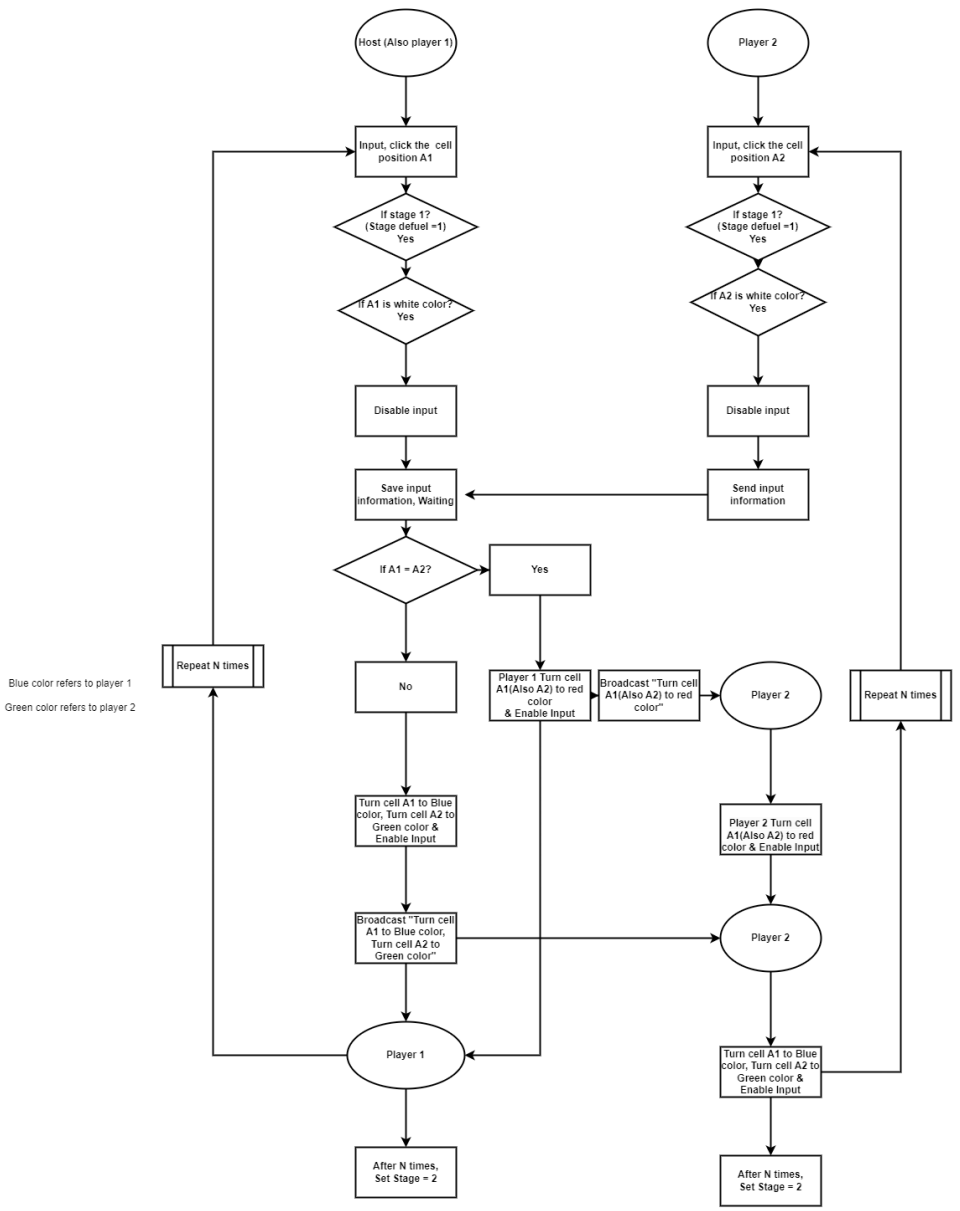
Appendix


Server and Host
Host (Also player 1)
Waiting for other player
Join, send ID
Player 2
Host (Also player 1)
Player 2
Load "Main Screen" for player 1
Broadcast "Game start"
Load "Main Screen" for player 2


Blue color refers to player 1
Green color refers to player 2
Host (Also player 1)
Player 2
Input, click the cell position A1
Input, click the cell position A2
If stage 1? (Stage defuel =1) Yes
If stage 1? (Stage defuel =1) Yes
If A1 is white color? Yes
If A2 is white color? Yes
Disable input
Disable input
Save input information, Waiting
Send input information
If A1 = A2?
Yes
Repeat N times
No
Player 1 Turn cell A1(Also A2) to red color & Enable Input
Broadcast "Turn cell A1(Also A2) to red color"
Player 2
Repeat N times
Turn cell A1 to Blue color, Turn cell A2 to Green color & Enable Input
Player 2 Turn cell A1(Also A2) to red color & Enable Input
Broadcast "Turn cell A1 to Blue color, Turn cell A2 to Green color"
Player 2
Player 1
Turn cell A1 to Blue color, Turn cell A2 to Green color & Enable Input
After N times, Set Stage = 2
After N times, Set Stage = 2

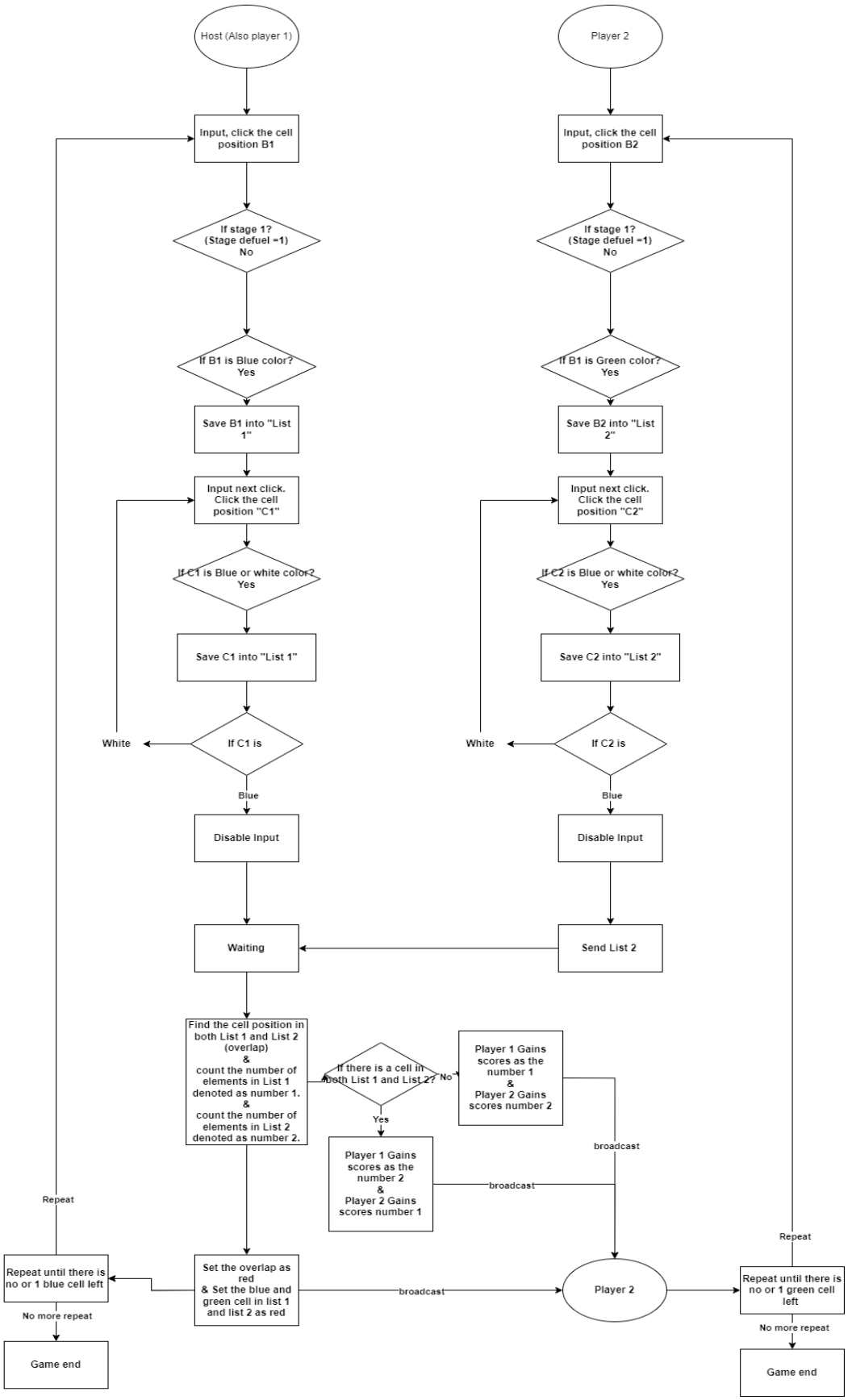


Figure A1. Flow chart of game logic.