ICONARP
International Journal of Architecture and Planning
Received: 22.02.2023 Accepted: 11.07.2023
Volume 11, Issue 2/ Published: 28.12.2023
Research Article *DOI: 10.15320 /ICONARP.2023.266 E- ISSN:2147-9380*
ICONARP

Ostrakinda: A Game-Based Learning Toolkit for Ancient Mediterranean Cities

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Abstract

The study develops the 'Ostrakinda' toolkit for teaching morphologies of ancient Mediterranean cities. The methodology consists of a triple structure involving design, play, and analysis phases. In the design phase, the level of interest and actual demands of students regarding game-based learning (GBL) and ancient cities were explored through pre-experiments. The play phase involved experimental studies conducted in courses and workshops, where both physical and digital toolkits were tested by a total of 331 students. The analysis phase aimed to evaluate the impact of the game by systematically addressing five research questions.

The results of the paired t-test confirm a significant difference in scores before and after playing the game, thus validating the effectiveness of the proposed strategy. Additionally, Chi-square (X^2) tests revealed significant relationships between the form of play and the level of abstraction in the game outputs. Individual and group experiences during gameplay were associated with various interactions, and group experiences particularly fostered competitive and collaborative learning. The extensive analysis using the GBL Design Scale, comprising ten critical factors (GBL-Fn), showed that the challenge factor (F8) had the weakest values, while fantasy (F5) and narrative (F6) had the highest values in the correlation matrix.

Overall, the study contributes methodologically and contextually to the existing literature, offering valuable findings for the future development of similar strategies in architectural education. However, it is important to acknowledge the limitations of this interdisciplinary study, particularly with regards to technical, cognitive, and archaeological aspects. Nevertheless, the clear and effective structure of the game holds promise as a valuable tool for learning.

Keywords:

Architectural Education, Game-based Learning, Mediterranean, Priene, Toolkit

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To cite this article: Şahin, M., & Eroğlu, B. (2023). Ostrakinda: A Game-Based Learning Toolkit for Ancient Mediterranean Cities. *ICONARP International Journal of Architecture and Planning,* Volume 11 (2), 838-865. DOI: 10.15320/ICONARP.2023.266

GBL IN DESIGN EDUCATION

Since the early 1950s, there has been a growing interest in the application of game-based learning (GBL) strategies in the field of architectural and urban design education. Educators took initial steps in using new urban games to understand urban complexities, as indicated by a notable report of Berkeley, 1968. A comprehensive bibliography titled 'Gaming Techniques for City Planning' was published in 1971, encompassing 95 books, articles, and 24 centers dedicated to exploring gaming techniques in city planning (Thornton, 1971). A more recent analysis of the Scopus database reveals that a significant majority of the 9,429 articles retrieved using the search query 'game-based AND learning' were published from 2007 onwards, with 36% originating from 2020 and beyond (search: June 23, 2023). These statistics provide clear evidence of the scholarly engagement in the field of GBL.

The literature review covers operational (Summers, 1979), serious (Abt, 1987), simulation (Feldt, 1995), and instructional (Kapp, 2012) games. Prior to the emergence of field-specific journals like the International Journal of Game-Based Learning (2011), volume 33 of the Journal of Architectural Education (1979) was devoted 'gaming' theme. This volume featured essential studies focusing on the GBL framework, design games, educational games designed with students, and games to be used in practice. Examining the pedagogical aspects and the effectiveness of GBL in design education are crucial. Hence, the following questions arise: What are the positive pedagogic impacts of game-based learning techniques on architectural students? Why is gaming successful as a teaching tool in design education? Games enhance understanding of complex issues, promote involvement in collaborative learning, increase students' attention in competitive or collaborative manner, reveal the consequences of immediate decisions, enable self-judgment, foster creativity through (co-)ideation, facilitate immersion with role playing, encourage broader participation, and facilitate the user-centered design process for cross-disciplinary groups (Summers, 1979; Berkeley, 1968; Kalay & Jeong, 2003; Brandt & Messeter, 2004; Vaajakallio & Mattelmäki, 2014; Dodig & Groat, 2019).

In North American and Western European universities, both modular and holistic games have been utilized to support urban planning (Thornton, 1971) and architectural design (Summers, 1979) studios. Thornton (1971) lists 26 games covering topics such as pollution, neighbourhood management, urban dynamics, and transportation. Alan Feldt, in his work 'Thirty-Five Years in Gaming,' traces the evolution of urban simulation/gaming and highlights his own contribution of 12 games, including the widely recognized CLUG (Feldt, 1995). In his work titled 'Operational Games in Architecture and Design' published in 1979, Summers presents six categories of architectural gaming, classified into two gaming styles: user-oriented games (focused on housing issues and facilities planning) and pedagogic games (covering construction,

DOI: 10.15320/ICONARP.2023.266

professional practice, problem-solving, and design issues) (Summers, 1979). There is a close relationship and simultaneous use of gaming in both architecture and urban planning. The origins of gaming in these fields can be traced back to military and business games, specifically gridded board games (Bonta, 1979; Keslacy, 2015).

How to design new GBL strategies into the courses to address various complex issues? It requires a deep understanding of the subject matter, learning objectives, and the actual needs of students. In this regard, elaboration of the pioneering approaches is important to gaining insights and positioning the proposed toolkit in emergent GBL practices (Table 1).

Table 1. GBL practices in architectural and urban design

Game (Acronym)	Year	Developer	Institution/Lab.	Description	References
Planning Operational Gaming Experiment (POGE)	1959	Francis H. Hendricks	City planning course at Cornell University	A zero-sum planning game dealing with strategies of two opponents to change zoning regulations in a previously zoned city.	(Hendricks, 1960; Feldt, 1966)
Michigan Experimental Teaching and Research Operation (METROPOLIS)	1960 -64	Richard D. Duke	Michigan State University (Environmental Simulation Lab)	A non-zero-sum planning game to reduce the gap between plan-makers and decision-makers showing changes in land use affected by decisions of the game actors.	(Duke, 1964; Berkeley, 1968)
World Peace Game	1961	R. Buckminster Fuller	Southern Illinos University	A worldwide game that has no losers, to facilitate a comprehensive design science approach for the global problems.	(Fuller, 1969)
Cornell/Community Land Use Game (CLUG)	1964 -65	Allen G. Feldt	Urban ecology and city planning Cornell University	A planning board game to experience some of the more basic economic forces effecting land use decisions of rapidly growing industial city	(Feldt, 1966; Berkeley, 1968; Feldt, 1995)
Simpolis	1967	Clark C. Abt	Abt Associates	An agitation game stimulating the participation in planning process major urban issues.	(Abt, 1987; Berkeley, 1968)
Instructional Housing and Building Simulation (INHABS)	1971	Cedric W. Green	Gloucestershire College of Art and Design	A neighbourhood-scale housing game to develop awareness of the effect of roles and their interaction on the total design process.	(Cedric, 1979; Summers, 1979)
ARCHITEST	1975	Luis H. Summers	Penn State University	A housing game to externalize the process of architectural evaluation and understand the rationale behind design decisions.	(Summers, 1979)
Heating and Air-conditioning (HAC)	mid-1970s	Juan P. Bonta	Ball State University	A boardgame to minimize total expenditures in heating and air-conditioning a home.	(Bonta, 1979)
KEEPS	1978	Henry Sanoff	School of Design at North Carolina State University	An urban participatory game to provide the group concensus desicions on preserving the environmental qualities in districts and towns.	(Sanoff, 1979)
MEDICAL	1979	Luis H. Summers	Pennsylvania State University	A facilities planning game consists of a kit to reach an agreement on of ptotoypical layouts	(Summers, 1979)
Cardboard City	1980	Marc Treib	University of California, Berkeley	A prototyping game that one analog builds upon another with full-size construction	(Treib, 1982)
River City	early -2000s	Chris Dede	Harward University	A multi-user game to learn through the virtually depicted industrial 19th century cities	(Clarce & Dede, 2009)
SpaceFighter	2007	Winy Mass	Delft School of Design & Berlage Institute	An urban simulation game to explore the challanges of the evolutionary city.	(Maas et. al., 2007)
ScarCity	2007	Axel Becerra Santacruz	School of Architecture at Sheffield	A boardgame to understand the design process of scarcity.	(Santacruz, 2019)
Dubinda	2010	Jordi Gascón Gutiérrez	Foro de Turismo Responsable	A game aims to reveal some of risks that the emergence of tourism activity with transnational capital for peasant societies.	(Gutiérrez, 2018)
Distributed Urban Game: Bloom	2012	Alisa Andrasek & José Sanchez	Bartlett School of Architecture	An interactive urban game to engages people in social play and collaborate in prototyping, generative design.	(Andrasek & Sanchez, 2012)
SuperBarrio	2017	MaCT students and experts	IAAC Master in City & Technology (MaCT)	An open-source virtual game to facilitate the citizen engagement to the neighbourhood design as one of the desicion maker.	(Markopoulou, 2020)
Polis PowerPlays (PPP)	2018	89 Friends	University of Queensland	An urban planning game aimed at teaching students and professionals the nuances of complex interactions and negotiations	(Pojani & Rocco, 2020)
EquiCity Project GoDesign	2019	Genesis Lab	TU Delft	A modular generative design game for mass-customization and optimization in participatory city planning.	(Bai et. al., 2020)
Townscaper	2020	Oskar Stålberg	Steam	A video game inspired by the Scandinavian cities to create their own town	(Harrouk, 2020)

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Several popular games have been extensively investigated within the urban context, including Monopoly (1900s), a strategic board game derived from The Landlord's Game; SimCity (1980s), an open-ended simulation game; Minecraft (2000s), a massively multiplayer online game; and Pokémon GO (2016), an augmented reality location-based mobile game. Notably, UN-Habitat published a manual on using Minecraft as a community participation tool in urban design projects (Westerberg & Rana, 2016). TechCrunch reported an average daily gameplay time of 33 minutes and an astonishing 21 million active users for Pokémon GO (Perez, 2016). Additionally, the EU-funded Public Play Space (PPS) project (2019-21), developed by a multidisciplinary consortium, cataloged 30 public space games focusing on environmental awareness, collective design, storytelling, learning, and decision-making (Farinea et al., 2021). Furthermore, the EU project titled 'Play the City' has incorporated 42 city games in 20 cities since 2010, utilizing community engagement as an integral problem-solving and collaborative decision-making tool (Tan, 2017). However, these popular games merely scratch the surface of the extensive body of literature encompassing a wide range of (un)published games. Some played in the laboratory by students, some played in the street by citizens (Berkeley, 1968).

Tóth (2015) conducted an analysis of 19 urban planning games, considering various criteria such as purpose, field of application, genre, technology, target group, location, and empirical results regarding their effectiveness. In our research, we examined the practices of Game-Based Learning (GBL) by considering a range of factors, including game types, gaming techniques, approaches, themes, contexts, number of players and required time, spatial scale, gains and outcomes, interfaces, and mediums. Understanding these essential components is crucial for designing effective GBL strategies.

- Game types: Roger Caillois defines four main types of play: competition (agon), chance (alea), vertigo (ilinx), and simulation (mimicry). These types can be combined in six theoretically possible dualities. Caillois also describes an evolution within each type, from paidia (active, spontaneous play) to ludus (structured, rule-based play) (Caillois, 1961). In our study, the examples provided in Table 1 primarily align with the type of mimicry, emphasizing role-playing and narrative elements: POGE, involving planners and developers; METROPOLIS, involving politicians, planners, administrators, and land developers; and INHABS, involving consumers, bankers, planners, press, builders, architects, associations, and local authorities. Additionally, there are examples that correspond to the agon type (POGE), alea type (Cardboard City), and ilinx type (River City).
- Gaming models: Schran and Kumpf (1972) classified gaming models in the field of environmental planning into three main groups based on the level of abstraction and formalization of reality: free, hybrid, and rigid games. These models exhibit different characteristics and approaches. In our study, we can observe examples that represent each

DOI: 10.15320/ICONARP.2023.266

of these categories. For instance, CLUG represents a predetermined set of factors, Townscaper and GoDesign utilize generative rules, POGE incorporates zones, and HAC involves codes of calculation. These examples reflect the more structured and rule-based nature of ludus games, in contrast to the more open-ended and flexible characteristics of free games (e.g., Simpolis) or the combination of both in hybrid games (e.g., METRO).

- Techniques and forms of integration: Summers (1979) defines two types of gaming techniques: holistic and nested. While many initial examples utilized holistic systems (such as Simpolis and Cardboard City), complex or sequential processes are also simulated by nested systems (such as ARCHITEST), which consist of diverse subsystems. GBL activities can also be categorized as immersive (involving an entire lecture or course) and modular (as independent activities), based on their form of integration into the class (Hartt et al., 2020). Modular activities are more commonly observed in the examples, as they are easier to implement. However, Cardboard Cities represents an immersive game played by students in the Environmental Design 3 studio at the University of California.
- Approaches: There are different approaches in games, including global and environmental approaches (e.g., World Peace Game), social and political approaches (e.g., METROPOLIS, KEEPS), economic approaches (e.g., CLUG, INHABS), computational approaches (e.g., HAC, ARCHITEST), and participatory approaches (e.g., Simpolis, SuperBarrio). Additionally, there is integration or synthesis between METRO and CLUG, leveraging their complementary structures in terms of social, economic, and political aspects.
- Themes & Contexts: Summers (1979) identified housing as the most gamed theme in architecture. In addition to housing, various themes were adressed, including global problems, major urban issues, environmental preservation, land use, transportation, scarcity, crisis, over-tourism, and facilities planning in relation to the subject matter and learning objectives. Developers involved in game creation encompass architects, urban planners, philosophers, sociologists, researchers, educational researchers, and game developers. The games draw inspiration from diverse contexts, such as Mexico (Scarcity), American cities (River City), Mediterranean coastal tourism destinations (Dubinda), Scottish villages (INHABS), Barcelona super blocks (Super Barrio), and Scandinavian cities (TownScaper).
- Spatial scale: The games examined, including World Peace Game (operating at a global scale), CLUG (utilizing an urban gridded board at a scale of 1:10,000 divided into 100 squares), INHABS (at a scale of 1:250), ARCHITEST (employing a kitchen modular scale), and Cardboard City (at a scale of 1:2 with full-size construction), exhibit varying spatial scales.
- Gains & Outcomes: Despite the competition generally revolving around making money, different types of players' gain (or loss), such as zero-sum (as observed in POGE) and non-zero-sum (as observed in

METROPOLIS). Additionally, games like World Peace Game and KEEPS are designed without losers, promoting a cooperative approach. Gerald Gutenschwager (1979) emphasized the game's role in education, highlighting its ability to simulate reality, foster strategic thinking, and enhance social awareness through the calculation of decision outcomes and actions. In GBL studies, Qian and Clark (2016) identify critical thinking, collaboration, creativity, and communication as targeted 21st-century skills to be developed as learning outcomes. The games draw attention to fundamental skills that support cooperation, heuristic learning, and creativity, such as matching, grouping, analyzing, designing processes, making decisions, problem-solving, and formulating strategies.

- Interfaces & mediums: Examples of game mediums include the utilization of urban space (e.g., PPS, Bloom) and the representation of city actors within the play space (e.g., POGE). The choice of interfaces plays a significant role in facilitating this representation. In earlier works, physical interfaces such as tangible, analog, crafting, grid planes, tokens, and board games were prominent. However, with the advent of the 20th century, digital interfaces such as video games, simulation-based platforms, mobile applications, augmented reality (AR), and virtual reality (VR) have become increasingly prevalent. Many games also employ both physical (e.g., Cardboard City) and virtual (e.g., Archville) versions, either for comparison or to enhance usability.

By exploring the described factors within the framework of GBL (Figure 1), we can gain valuable insights into the diverse nature of play. This understanding enables us to recognize the unique experiences and opportunities for learning, engagement, and the development of effective strategies that different types of games offer.

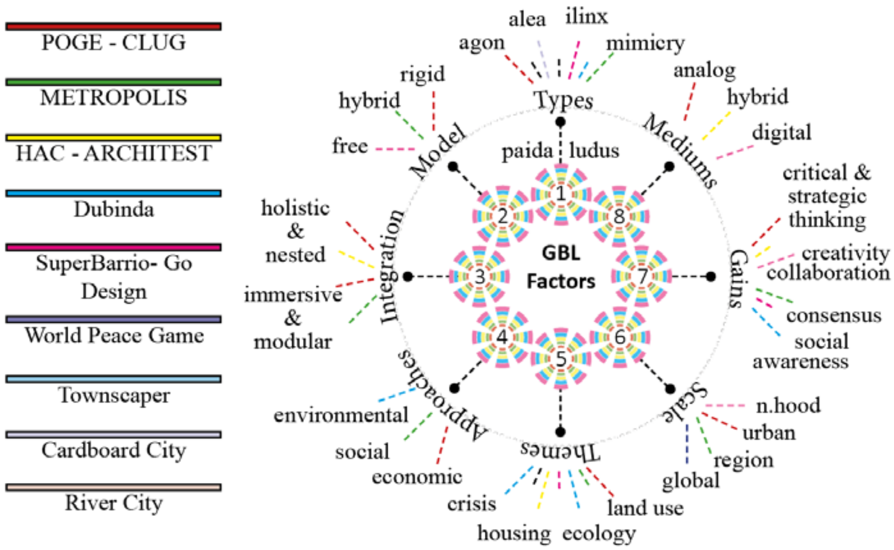

Figure 1. Framing GBL components according to the planning and design games.

The factors mentioned can be further expanded by considering sub-attributes such as the number of players and sessions. For example, HAC

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involves 20 players and requires 2/3-hour sessions (Bonta, 1979), while PPP accommodates 20 to 60 players. Dubinda is designed for 4 to 16 players and requires a 3-hour session, and Cardboard Cities involves 75 students over several weeks. Additionally, there are massively multiplayer online games like Super Barrio, Space Fighter, and River City that create social gaming environments. These components of GBL practices intersect in the complexity of the city and the involvement of different actors in a fantasy setting.

Ostrakinda, a children's game played with seashells or broken amphora pieces in ancient Greece, has served as the inspiration for a dichotomic concept that represents the dual nature of Mediterranean cities, encompassing both the ancient and modern aspects (Baran, 1974). The objective of this study is to develop an open-ended GBL toolkit called Ostrakinda, which is specifically designed to enhance the teaching of ancient Mediterranean cities and to introduce playful strategy into regular architectural education classes. To achieve this aim, our research has delved into the exploration of tangible-digital interfaces, individual and collaborative experiences, and analysis methods supported by artificial intelligence within the game. The paper's structure is as follows:

- The next section presents an overview of the methodological workflow utilized in designing, implementing, and analyzing the Ostrakinda toolkit. It provides a detailed description of the toolkit, including its conceptual background, gridded frame, (non)digital interfaces, and the complementary structure of its components.
- Following that, five research questions are examined through the analysis of gameplay interactions, output, and participants' feedback to clarify how interactions occur in the play.
- Subsequently, the paper discusses the results of experimental studies conducted in different periods and settings, offering a comprehensive analysis of the findings.
- Finally, the paper concludes by highlighting the potentials and limitations of the Ostrakinda toolkit, accompanied by recommendations for future studies.

METHODOLOGY

The research methodology encompasses three distinct phases: design, play, and analysis. During the design phase (1), researchers develop physical or digital toolkits aligned with the research objectives. These toolkits are subsequently assessed within workshop and (online) classroom settings during the play phase (2). Finally, the analysis phase (3) involves measuring and evaluating the individual or collaborative gameplay experiences. The resulting findings generate feedback that informs the modification of the game within the action circle. Throughout these phases, diverse methods and tools are employed, as illustrated in Figure 2.

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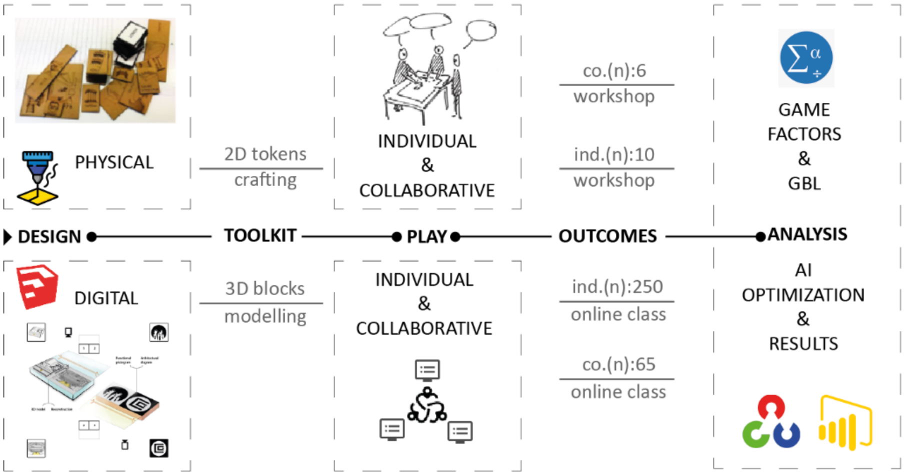

Figure 2. Research methodology.

Design of Toolkit

Phase 1 focuses on the ideation of the game, considering its relations (tasks and rules), components (cards and grids), and representations (pictograms and diagrams). The primary goal of Ostrakinda is to provide a practical and interactive way of teaching concepts, functions, and values related to ancient cities. To achieve this, it is essential to simplify and abstract the essential elements and morphologies of the city. In the initial tests, the city of Priene, known for its grid plan in the Mediterranean geography, was chosen as the model. Several factors influenced the selection of this city, which can be highlighted.

The urban development in ancient Hellenic cities is divided into natural and Hippodamian systems (Doxiadis, 1964). Aristotle discusses Hippodamos' grid-based urban planning system, which categorized cities into three zones: sacred, public, and private according to Doxiadis (1964), small-scale cities, which constitute the majority, typically have an average size of approximately 180 hectares. Wycherley (1962) characterizes the city of Priene as a "model Greek city" due to its small-scale nature. Similarly, Gates (2015) emphasizes that the modest characteristics of Priene exemplify the ancient Greek city in a generic and distinct manner, in contrast to more affluent and extensively reconstructed centers like Athens. Cities like Priene, Olynthus, and Miletus feature the essential elements of the Hellenic city, with a grid (checkerboard) urban pattern of simple, open, and practical streets intersecting at right angles. Priene was selected as the foundational model for initial tests due to its clear urban elements, well-preserved nature, and grid plan. Game boards were created based on the city grids using abstraction (Figure 3).

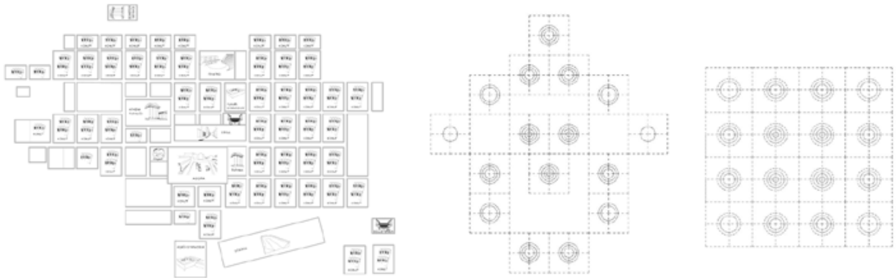

Figure 3. Level of abstraction of the grid frames.

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To enhance the effectiveness of the board, it is essential to create both 2D and 3D representations of urban elements. These representations can be crafted manually or digitally modeled. A tangible interface can be utilized, consisting of diverse tokens or blocks in the digital medium. These tokens have two faces, enabling the display of various illustrations and notes. There are 12 different tokens in total. The city was rebuilt in the 4th century, and housing and public spaces were formed based on the grids. In the east-west direction, the center where the main streets pass is reserved for the Agora. The Agora, located in the center of the lower part of the city that expanded around the acropolis's hills, is where the people come together. Stoas and temples dominate the Agora. The Stoa, with their colonnaded structures, define the (half) surrounding area and provides shelter for diverse uses like commercial activities, small temples, and meeting places within its units. While the east Stoa hides a small temple, the meat and fish (food) market is behind the west stoa, and behind the north or sacred stoa, the Bouleuterion (council room) is located in Priene. (Wycherley, 1962). Public buildings such as the Bouleuterion (the meeting place of the city council) and the Prytaneion (the state guesthouse) have a variety of places in Wycherley's composition. However, these public buildings are generally located around the Agora. In addition to public and sacred spaces, the housing texture in the urban grid system shows the megaron, prostas, and peristyle typologies (Abbasoğlu, 1999). Doxiadis emphasized the human scale provided by the stoa formation's open, semi-open, and closed composition (Doxiadis, 1964). The city also has building blocks contrary to the grid order, as in Peiraeus. The stadium, terraced in a restricted area on hill slopes, is an example of placement contrary to the grid (Gates, 2015). It is seen that the topographical character is effective in positioning and the land use with terraces, especially enormous structures like the theatre, stadium, and gymnasium.

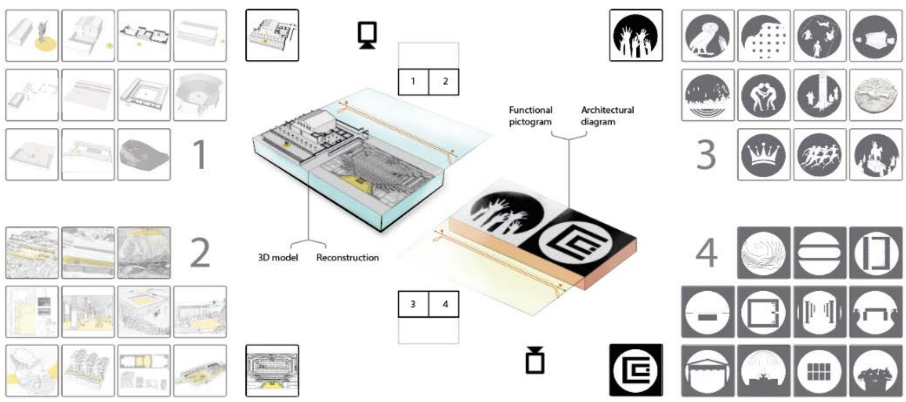

Figure 4. Complementary structure of the tokens/blocks.

Ostrakinda represents these elements in the 12 (two-sided) token/block system: Token 1 (Sacred Center / Acropolis), Token 2 (Social center / Agora), Token 3 (Democracy / Bouleterion and Prytaneion), Token 4 (Entertainment / Theatre), Token 5 (Trade / Macellum), Token

6 (Discipline / Gymnasium), Token 7 (Multifunctional / Stoa), Token 8 (Hygiene and socialization / Balnea and Thermae), Token 9 (Sacred / Temples of Athena and Zeus), Token 10 (Competition / Stadion), Token 11 (Death / Necropolis), Token 12 (Habitation / Megaron, prostas and peristyle houses) (Figure 4).

Play with Toolkit

In the second phase, Ostrakinda is tested in various environments, both individually and collaboratively. The toolkit, which has been designed and produced, is integrated in a modular manner into courses and workshops involving architecture and planning students. Within the context of the city of Priene, three crucial interactions are facilitated through the utilization of the board (grid frame) and its components (tokens). These interactions include the creation of networks between complementary tokens, the comparison and analysis of their functions and characteristics, and the appropriate positioning of the tokens on the grid. Furthermore, the group experiences highlight the importance of player interaction. The other critical point explored in Phase 2 is the establishment of a set of rules for the game. These rules aim to create a flexible, adaptive, and interactive tool in the game with abstract representations of the components and the neutral character of the grid board. Participants are provided with a template that includes game components, allowing them to create scenarios tailored to their preferences and learning objectives.

Ostrakinda tests were conducted through experimental studies within the action circle. Initially, the analog game (2D toolkit) was tested, followed by the digital game (3D toolkit) built upon the insights gained from the analog tests. These experimental studies were integrated into online classes and workshops, allowing both individual and collaborative gameplay. The testing process encompassed ideation, interface design, modeling and crafting, experimental study, analysis, and customization (Figure 5). The development of the game, which commenced in 2019, is an ongoing long-term research project that incorporates feedback obtained from experimental studies conducted in 2020, 2021, and 2022.

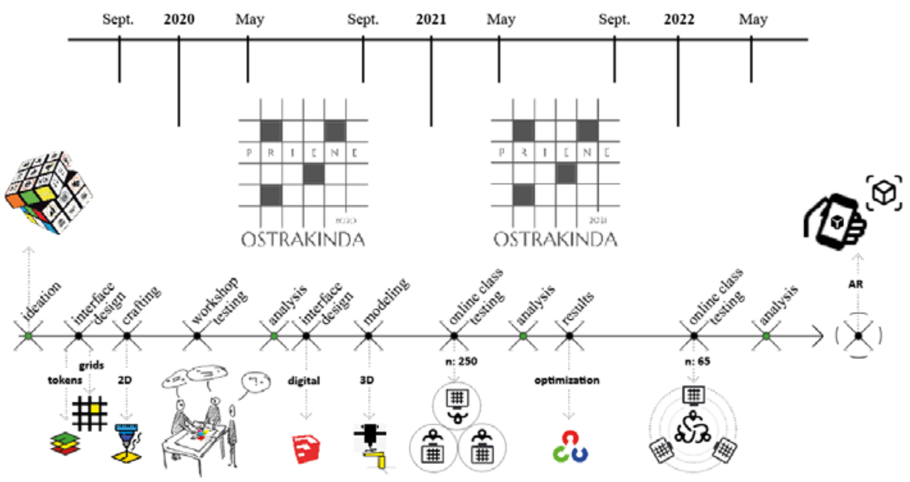

Figure 5. Essential design phases of Ostrakinda.

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In the initial experimental study (Figure 6), a scaled board grid (1/20,000) is employed, featuring abstracted pictograms and diagrams on meticulously crafted physical tokens. These tangible tokens are utilized in both collaborative and individual gameplay sessions, facilitating valuable insights, findings, and critiques for the modification and refinement of the game.

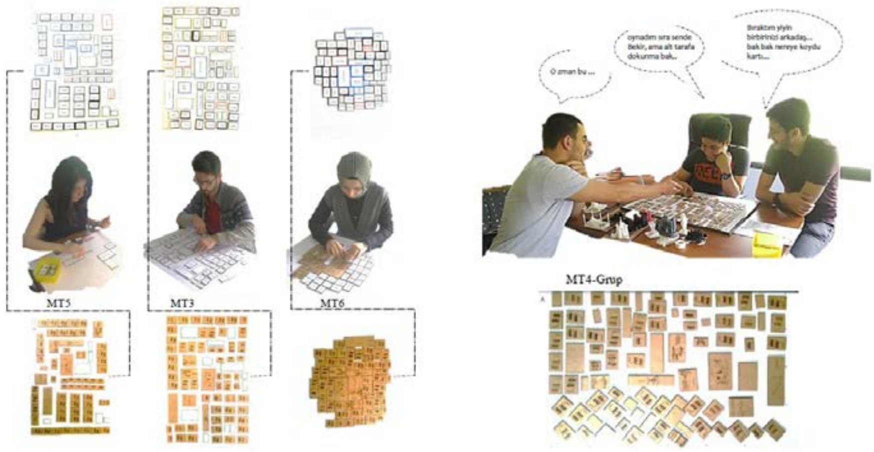

Figure 6. Collaborative and individual experiences (form of play).

Physical testing of the toolkit is limited by the number of crafted prototypes available. On the other hand, the digital toolkit was tested with the Zoom application, using breakout rooms for collaborative play of students. This allows for mass participation, process automation, and the analysis of computational outputs, offering distinct advantages in the digital environment. It is important to consider the affordances provided by both the physical and digital environments for player interaction (conflicts, co-decisions, and social learning) and the representation of urban elements. While the game's fundamental structure remains unchanged, the 2D tokens in the tangible toolkits are transformed into 3D blocks within the digital environment. However, the tools used in the experimental studies may differ between the physical and digital environments based on measured factors.

Analysis

The evaluation of a game's effectiveness encompasses various factors commonly identified in current studies. May's evaluation frame for gaming-simulations in architecture emphasizes involvement, learning derived, incentive to play, clear rules and instructions, good use of time, choices of strategy, stimulation of independent thought, validity of simulation, and having fun (May, 1979). Shi and Shih propose factors such as game goals, game mechanism, game fantasy, game value, interaction, freedom, narrative, sensation, challenges, sociality, flow, and mystery to construct a game-based learning (GBL) design model (Shi & Shih, 2015). In phase 3, an integrated model is used to evaluate Ostrakinda's effectiveness and compare it to the current and general framework. Five research questions (RQs) are addressed through the game process, outputs, and participants' feedback to improve the effectiveness of the toolkit based on subject matter, learning objectives, and the actual needs of students. Various tools and methods, including statistical analysis, data visualization, and optimization techniques, are employed in line with the RQs (Figure 7).

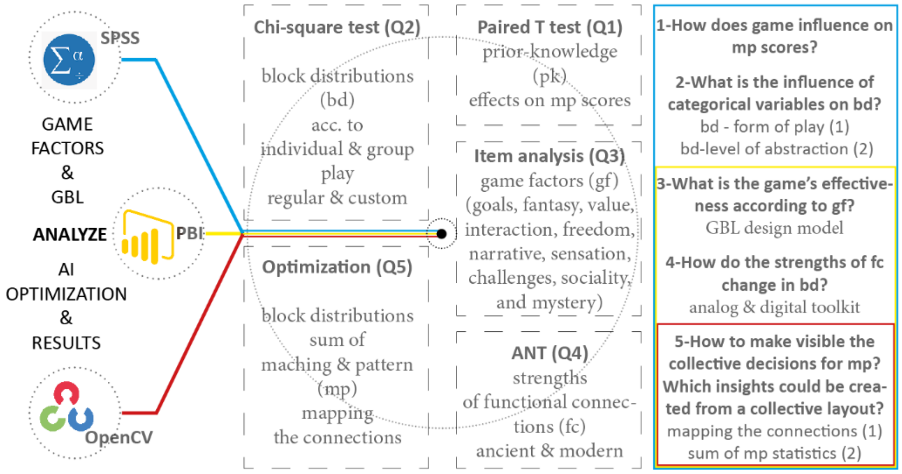

Figure 7. Research questions and data analysis tools.

The effects of the pre/post-game are measured using the Paired Samples t-Test, which compares the means taken from the same group (Q1). The relationships between categorical variables are measured using the Chi-square test (Q2). To ensure comparability with related studies, the general effects of the game are measured using the Game-Based Learning (GBL) item test (Q3). The Actor Network Theory (ANT) by Latour is employed (Q4) to reveal the strength and variation of connections and make the networks between the actors visible. The main actors in the play include the complex urban network, abstract interface tokens or blocks representing ancient-modern city components, type of grids on the game board, participants (individuals or groups), and the environment. ANT analysis allows for the examination of interactions between actors and the dominance of certain actors in the network (Latour, 2005). The network comprises the main focal points, such as public spaces (especially the city square), as well as mediator or secondary relations in various forms. ANT involves measuring three indicators: relationships between variables, distribution of functions based on distance, and inter-functional networks. Furthermore, the goal is to design a computational analysis model using optimization techniques to extract valuable insights from the large volume of game outputs (Q5) and assess its usability.

Experimental studies were conducted as part of the triple structure methodology (design, play, and analysis), involving the analysis of game outputs and the measurement of game effects through questionnaires.

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RESULTS

Ostrakinda is analyzable based on the essential GBL factors in planning and design games, considering aspects such as type, model, integration, approaches, themes, scale, gains, and mediums (Figure 8).

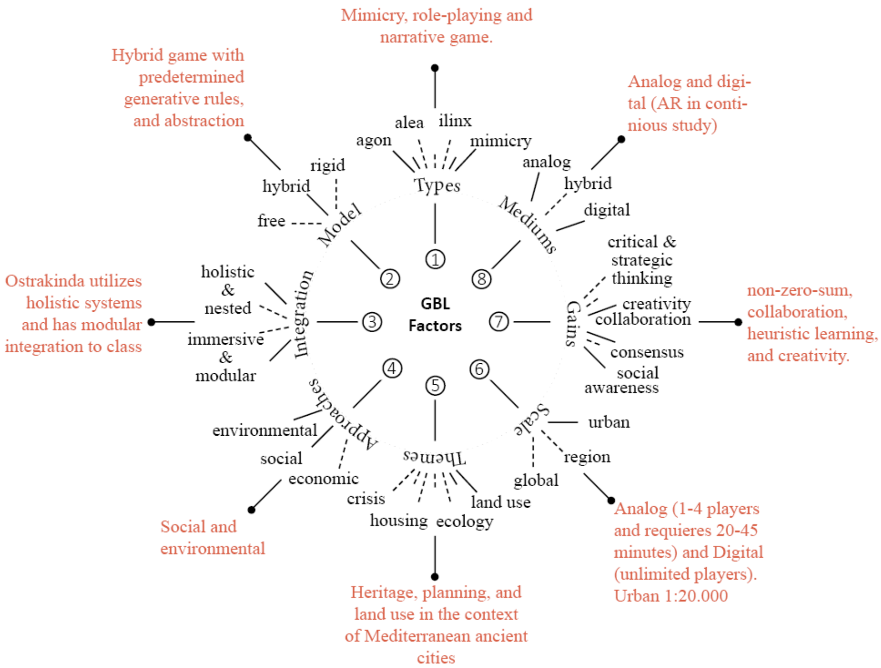

Figure 8. GBL components in Ostrakinda.

The identified GBL factors are pertinent to the RQs outlined in the methodology. This analysis structure can be expanded and refined by incorporating additional factors and sub-categories. It is crucial to further develop this structure based on the obtained results and reassess its alignment with previously analyzed GBL practices.

Pre-experiment

The initial research findings are focused on the problem area and target group of the study. Prior to the experimental studies, questionnaires were used to assess the architectural students' preliminary knowledge levels regarding ancient cities. The survey, conducted in 2021 and 2022, included three factors: students' level of interest in ancient cities, types of resources they utilize, and their prior knowledge of ancient cities. The pre-experiment involved a significant number of participants, with a gender ratio of 83 males to 171 females and an average age of 21. The level of interest in ancient cities was evaluated through questions related to visiting and familiarity. The findings were mapped on a national scale, indicating the locations of the students who participated online due to the COVID-19 pandemic and the distribution of ancient cities throughout the country. The map displayed increasing or decreasing colored rings to represent the level of familiarity and visiting frequency. While the participants were primarily concentrated in Istanbul, there was notable diversity across other cities in the country.

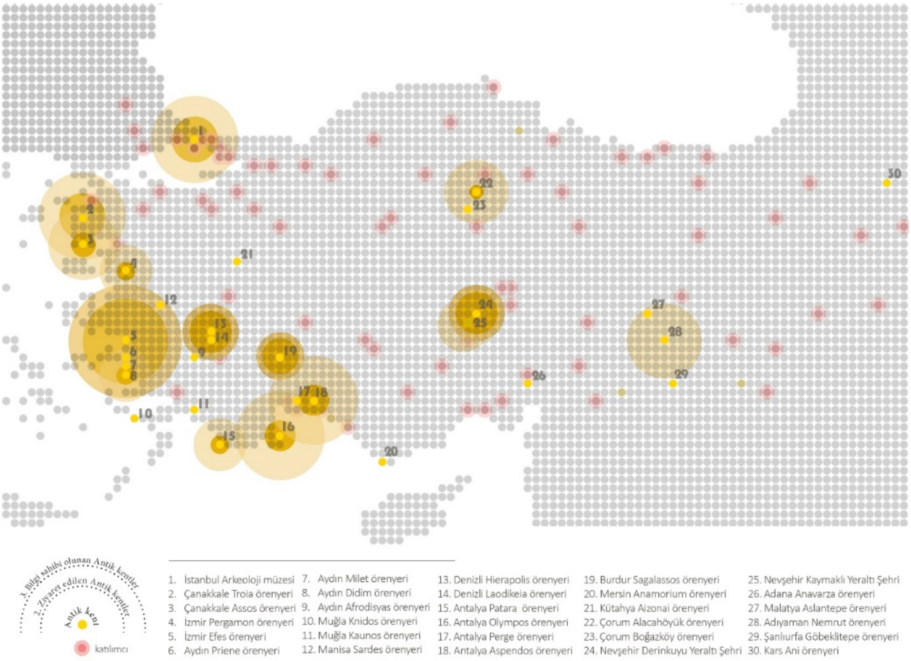

Figure 9. Mapping of level of interest of the participants for ancient cities in Turkey.

The participants' visits to ancient cities align with the tourism statistics of Turkey. The most frequently visited destinations, such as İzmir-Efes (36%), Çanakkale-Troia (26%), Antalya-Olympos (22%), and Nevşehir-Derinkuyu (15%), can be observed based on the 2019 visitor statistics of museums and archaeological sites provided by the Ministry of Culture and Tourism. However, familiarity with ancient cities exhibits a more dynamic pattern. For instance, while the familiarity level with the Şanlıurfa Göbeklitepe archaeological site is 52%, the visitation rate is only 5%. The findings regarding the type of resources used by students highlight the significance of higher education, travel experiences, and social media. Moreover, prior knowledge (pk) statistics reveal the participants' ability to match various concepts and terminologies associated with ancient cities. While Stadion, Temple, and Thermae are among the well-known terms, Gymnasium, Stoa, and Bouleuterion tend to be more confusing. At the end of the pre-test, students' interest in experiencing the GBL tool for ancient cities is measured using a 5-point Likert scale, with an average score of 4.23 (n: 254). These preliminary findings support for the development of alternative tools such as Ostrakinda.

Maching and Pattern Scores

The survey data collected before and after the game underwent statistical analysis using a Paired Samples t-Test in the SPSS software. The significant difference between the pre-test knowledge (pk) levels and the post-game scores highlights the impact of the game. Specifically, the scores of a group comprising 87 participants enrolled in an online class,

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where the game was individually played, underwent meticulous examination. The scoring system employed ranged from 1 to 10. The interrelationships among the variables, encompassing pk, matching score (Score_M), and pattern score (Score_P), were thoroughly scrutinized. The analysis yielded substantial evidence of a significant association among these variables, with a two-tailed significance value of less than 0.01. Of notable interest, the strongest positive correlation coefficient of 0.596 was observed between the matching and pattern scores, thereby indicating a robust correlation between these factors (Table 2).

Table 2. Paired Samples t-Test

Paired Samples T Test		Correlations	Mean	sd	95% Confidence Interval of the Difference		t	df	Sig.
					Lower	Upper			
Pair 1	PK & Score_M	,376**	3,91	3,12	3,24	4,57	11,68	86	,000
Pair 2	PK & Score_P	,279	0,03	2,90	-,59	,64	,074	86	,941
	Score_M&P	,596**	3,93	2,50					

**Correlation is significant at the 0.01 level (2-tailed).

Categorical Variables for Block Distributions

Chi-square (X^2) tests are employed to analyze relations between the form of play and level of abstraction in the block distributions (bd) obtained from experimental studies. The bd were decoded based on the locations, including center, in-between, and periphery positioning on the grid. The first factor, form of play, explored the effects of collective and individual experiences, while the second factor, level of abstraction, investigated the impact of realistic and abstract grid planes on bd. The sample-sensitive X^2 test was conducted for mass participation and diverse game outputs of digital toolkit experiences. The OpenCV (Open-Source Computer Vision Library) was utilized for capturing the coordinates of the bd in massively game outputs. The bd data and the two-factor variables were then imported into the SPSS software for analysis. The X^2 and p values were calculated to determine the relationship between categorical variables and distributions of 12 blocks (Table 3). The results show a significant relationship between variables. To further refine the analysis, the position codes of the 12 blocks (center, in-between, and periphery) were simplified into true and false categories within the pattern, and the tests were repeated. Similar to the initial X^2 test, block diversity was taken into consideration, leading to a significant relationship between the variables. Notably, the level of abstraction value changed from 81,902a to 88,899a, while the form of play value shifted from 278,459a to 253,983a in these subsequent tests.

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Table 3. Chi-square test results for block distributions

Chi-square X^2 Test			Block Distributions: Count-Expected Count											
			B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
realistic			54	62	61	47	74	46	51	50	65	50	125	257
			45,7	48,5	51,3	40,0	56,9	36,6	44,0	42,9	52,4	41,2	112,2	271,2
form of grid	X^2	**81,902****												
	p	**,000**												
abstract			27	24	30	24	27	19	27	26	28	23	74	224
			35,3	37,5	39,7	31,0	44,1	28,4	34,0	33,1	40,6	31,8	86,8	209,8
individual			55	56	59	44	69	38	52	51	64	45	170	444
			67,8	71,9	76,1	59,4	84,5	54,4	65,3	63,6	77,8	61,1	166,5	402,4
form of play	X^2	**278,459****												
	p	**,000**												
group			26	30	32	27	32	27	26	25	29	28	29	37
			13,2	14,1	14,9	11,6	16,5	10,6	12,7	12,4	15,2	11,9	32,5	78,6

**p< 0.01 level (2-tailed).
[a] 0 cells (0,0%) have expected count less than 5. The minimum expected count is 10,62.

Game's Effectiveness

A total of 65 students participated in the group experimental studies conducted in 2022 (Figure 4). These groups consisted of triple (n: 9), double (n: 15), and quadruple (n: 2) students. This sample was specifically chosen to assess the game factors, given its inclusion of collaborative experiences. Descriptive statistics were employed to analyze the effectiveness of Ostrakinda, as presented in Table 4. The factors indicate strong performance (above 4), except factor 8 (challenges). The factors indicate strong performance, with scores above 4, except for factor 8 (challenges). Notably, the scores of group gameplays show slight variations when compared to individually experienced games in 2021 (n: 250). Interestingly, values for individual (i) and group (g) experiences show similarities, such as freedom (4.14 (i) and 4.12 (g)), sensation (4.01 (i) and 4.03 (g)), and interaction (4.09 (i) and 4.23 (g)). However, there is a significant difference in challenge values between individual (3.38) and collaborative (3.82) experiences. Hence, form of play effects should be reconsidered and discussed.

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Table 4. Descriptive statistics according to game factors (scale adapted from GBL design model of Shi & Shih)

Factor	Items	M		SD
(1) Game Goals	(a) The tasks (mp) have clear goals.	4,34	**4,32**	,69
	(b) The tasks are interesting.	4,26		,80
	(c) I'd like to complete the goals.	4,35		,76
(2) Mechanism	(a) The genre and gameplay are clear.	4,17	**4,22**	,95
	(b) The game rules are clear.	4,18		,85
	(c) I like its gameplay (mp).	4,29		,98
(3) Interaction	(a) The operational process is easy and intuitive.	4,23	**4,23**	,79
	(b) The block and grid tips are clear and guiding.	4,02		,94
	(c) The interaction with two-faces blocks is fun.	4,43		,68
(4) Freedom	(a) The selection and moves are easy to control.	4,26	**4,12**	,92
	(b) I can play the game in various ways/strategies.	4,00		1,0
	(c) There is enough movement space and variety.	4,11		,92
(5) Fantasy	(a) The style and overall appearance is consistent.	4,26	**4,34**	,85
	(b) The drawings and models fits its context.	4,34		,81
	(c) The story and components of the game match.	4,42		,68
(6) Narrative	(a) The game has rich content of ancient cities.	4,22	**4,31**	,82
	(b) The plot (grid pattern and tokens match) is logical.	4,32		,81
	(c) I'd like to follow the story's development.	4,40		,84
(7) Sensation	(a) It is convenient to experience in SketchUp.	4,00	**4,03**	1,1
	(b) Tools (camera, blocks handling) are functional.	3,97		1,0
	(c) Sound and interface need to be developed.	4,11		1,1
(8) Challenges	(a) The game is challenging.	2,85	**3,82**	1,1
	(b) Team makes it easier to achieve game goals.	4,38		,84
	(c) Different difficulty levels should be developed.	4,23		,93
(9) Sociality	(a) It's fun to play as a team.	4,49	**4,36**	,81
	(b) The game allows to compete and cooperate.	4,49		,83
	(c) I like to compete and cooperate with others.	4,09		1,0
(10) Mystery			**4,10**	
	(a) The game has surprises and interesting things.	4,05		,94
	(b) The game increased my interest for ancient cities.	4,15		,94

Correlations between factors were analyzed in SPSS. The strongest correlation was observed between factors 5 (fantasy) and 6 (narrative), while factor 8 (challenge) showed the weakest relationship with other factors (Table 5)

Table 5. Correlations between game factors

Factor Correlations	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	1	,453**	,602**	,425**	,600**	,667**	,499**	,331**	,531**	,471**
(2)	,453**	1	,650**	,680**	,467**	,430**	,530**	,144	,460**	,386**
(3)	,602**	,650**	1	,680**	,607**	,662**	,614**	,243	,537**	,546**
(4)	,425**	,680**	,680**	1	,596**	,576**	,597**	,239	,579**	,455**
(5)	,600**	,467**	,607**	,596**	1	,727**	,552**	,502**	,576**	,594**
(6)	,667**	,430**	,662**	,576**	,727**	1	,658**	,442**	,581**	,500**
(7)	,499**	,530**	,614**	,597**	,552**	,658**	1	,318**	,534**	,411**
(8)	,331**	,144	,243	,239	,502**	,442**	,318**	1	,610**	,466**
(9)	,531**	,460**	,537**	,579**	,576**	,581**	,534**	,610**	1	,639**
(10)	,471**	,386**	,546**	,455**	,594**	,500**	,411**	,466**	,639**	1

**Correlation is significant at the 0.01 level (2-tailed).

Distributions And Functional Networks

Besides online experimental studies, the physical toolkit was also tested in 2019 and 2020, yielding significant findings. The initial prototypes featured nine cards with varying levels of abstraction. The game objectives focused on the positioning of two-faced cards without matching. These findings influenced the development of the digital toolkit interface and the inclusion of more complex tasks. Testing involved both group (n:6) and individual play (n:10). The evaluation process included a survey capturing participants' experiences and addressing students' actual needs. Key tactics during the game included central planning, land use, landmarks, human scale, and establishing axes. Collaborative experiences tended to be longer due to discussions and consensus-building. Survey feedback highlighted the desire for increased card variety, inclusion of different and interesting cards, enhanced visual illustrations, and general improvements in game rules.

Function rankings and connection strengths of game blocks were used in collaborative urban design research (Bai et al., 2018). By employing a similar analysis, the network of adjacent tokens provided insights into the decision-making process for each city component on the grid. Within the framework of Actor-Network Theory (ANT), tokens were assigned weights based on network counts. Initially, the distance of functions placed in the grid system from the center was examined. The analysis revealed that cultural, official, trade, education, and multi-purpose buildings were positioned closer to the center. The variation between the color scale and the distribution of functions can be seen in the graphical

DOI: 10.15320/ICONARP.2023.266

illustration. Following the distance-based distributions, networks between different functions (tokens) were mapped (Figure 10).

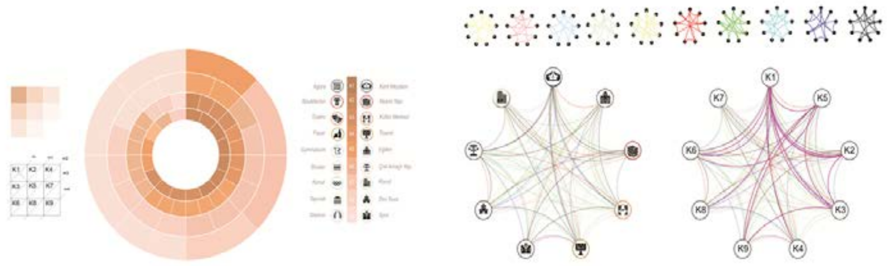

Figure 10. Distance-based distributions (left) and functional networks (right).

Collective Layout

When game outputs reach a massive scale that exceeds manual analysis capabilities, it becomes necessary to develop advanced analysis methods. In this regard, for the voluminous outputs of online experimental studies involving a large number of participants, a collective layout has been devised by integrating OpenCV and PowerBI. This approach facilitates practical and analytical optimization of the data. Initially, the visual grid and block data captured by the default game cameras are processed using a custom algorithm implemented in OpenCV. This algorithm extracts the coordinate information of the blocks involved in the matching and pattern tasks. Subsequently, the extracted data can be dynamically and parametrically analyzed using PowerBI, providing valuable insights (Figure 11).

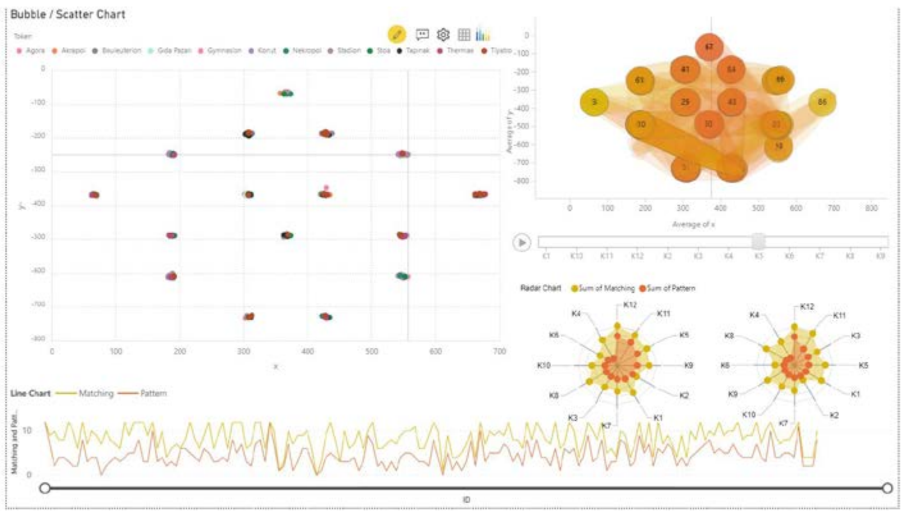

Figure 11. Open CV and Power BI analysis for bd results.

In Figure 11, the analysis panel presents four queries for data analysis: a bubble/scatter chart (1) for the sum of bd, an impact bubble chart (2) for block distributions by ID, a radar chart (3) for the sum of mp, and a line chart (4) for the relationship between pk and mp. The data can be analyzed parametrically using various filters, such as selected blocks, experimental studies, and ID. Figure 12 provides a graphical example relevant to Q1.

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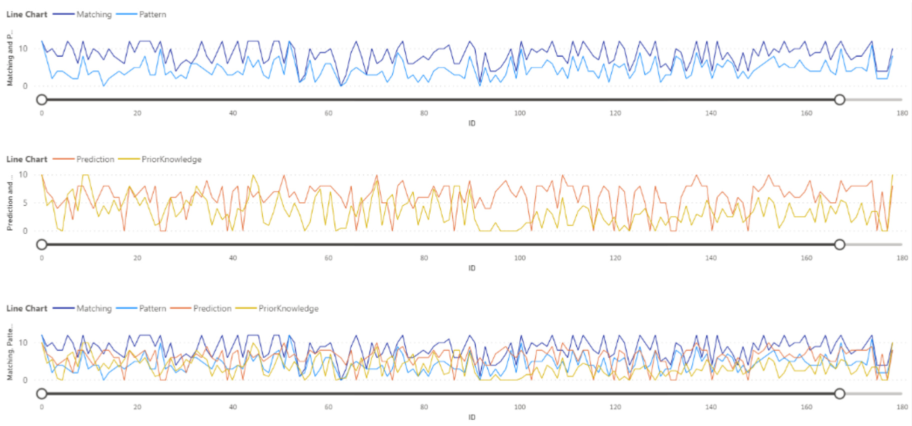

Figure 12. Line chart of pk and mp values.

Similarly, the distributions of the blocks offer comprehensive depictions of bd (Q2). For instance, K1 (acropolis) demonstrates a scattered distribution in the peripheral areas, while K12 (dwelling) exhibits a more concentrated distribution around the center (Figure 13).

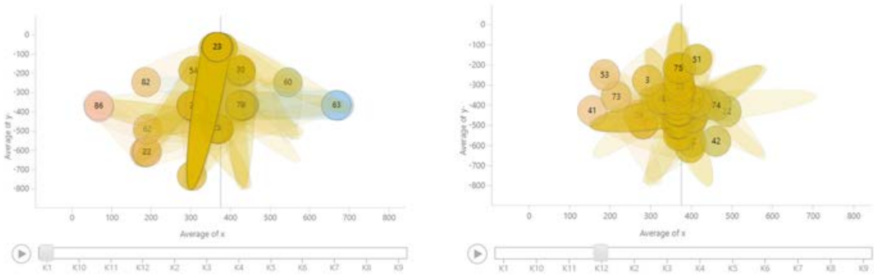

Figure 13. Impact bubble chart of bd.

DISCUSSION

The findings provide an opportunity to discuss each research question (RQ) separately. These RQs are interconnected with the objectives of the game and examining them individually enables a deeper analysis of their specific impacts. By delving into each RQ, a more holistic view of the game's overall effects can be obtained.

RQ1- How does the game influence matching and pattern scores? The effects of the game on matching and pattern scores were examined through a paired t-Test analysis. The results, presented in Table 2, show an increase in scores before and after gameplay. There appears to be a correlation between Score Matching and Score Pattern, as well as between PK and Score Matching. However, no significant correlation was found between PK and Score Pattern. These findings suggest the need for further discussion regarding the difficulty levels of both game tasks and their relationship with PK. While PK assessments directly address matching tasks, they do not encompass questions related to blocks, token positions, and urban pattern relationships. Thus, it is necessary to enhance the measurability of the PK assessment content. Moreover, the observed before-after effects not only confirm the positive effects of the game but also serve to highlight areas for further improvement within the action circle.

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RQ2- What is the influence of play form and abstraction level on block distributions? Chi-square test results show significant relationships between block distributions and categorical variables. Consequently, it is necessary to identify and enhance the positive effects of grid forms and play configurations as optimal setups. Although evaluating the impact on game scores may be complex due to the interconnectedness of various factors, it does confirm the overall significant effects on block distributions. To encourage flexibility, learning, interaction, and creativity, it becomes important to offer diverse variations of grids and tokens in both realistic and abstract forms based on subject matter and learning objectives. Additionally, it is important to recognize that individual and group experiences within the game can elicit distinct interactions and promote learning through discussion, consensus-building, and competitive interaction.

RQ3- What is the game's effectiveness according to GBL factors? Descriptive statistics offer a comprehensive framework for assessing the effectiveness of Ostrakinda in terms of GBL factors. Overall, the results validate the usability of Ostrakinda. However, it is worth noting that factor 8 (challenges) shows lower positivity levels compared to other factors. Also, there is a significant difference in factor 8 between individual play (3.38) and collaborative play (3.82) experiences. This observation suggests that there is indeed room for improvement, particularly in factor 8, which specifically pertains to individual play. To address this, various modifications can be taken into consideration, including enhancing competition, refining scoring systems to incorporate rewards, diversifying game components, adjusting task difficulties, and improving the visibility of immediate decisions. On the other hand, the mean scores of game goals, fantasy, narrative, and sociality indicate strong performance. This distinction may be attributed to clarity of the game's rules and instructions, the attractiveness of the subject matter, and the decision-making processes that facilitate cooperation among players. It is important to note that a high score is not necessarily required for each factor. Therefore, in the ongoing research process, it is crucial to carefully weigh and prioritize the different GBL factors to ensure a more effective and well-rounded game design. Additionally, the GBL model employed in this paper (Shi & Shih, 2015) could be enhanced to create a more robust assessment scale tailored for design education, as suggested by May's gaming-simulations framework (May, 1979).

RQ4- How do the strengths of functional connections change in block distributions? The strengths of functional connections within bd make the relationship between diverse actors in the game visible. This enables a comprehensive analysis of game outputs, considering factors such as the abstraction levels of grids, the number and variety of tokens, rules and instructions, time utilization, and strategic choices. The patterns based on center and periphery positioning and relationships between various tokens are diversified and indicate some mostly repeated tactics and strategies in the results. However, two drawbacks have been identified that prevent making consistent inferences. Firstly, it is crucial to measure the decision-making, iterative, and dialectic processes rather than solely focusing on the game outputs. Particularly for group interactions, protocol analysis plays a vital role in understanding the process dynamics. Secondly, analyzing the protocols and outputs within an online system with numerous participants poses a significant challenge. To address these limitations, attempts have been made within the scope of RQ5 to enhance the analysis process.

RQ5- How to make visible the collective decisions? Which insights could be created from a collective layout? The integration of OpenCV and PowerBI offers a strategic approach to analyze the extensive game outputs. The choice of analysis and visualization formats depends on the specific factors being measured. Among these formats, a line chart can effectively represent collective decisions, while an impact bubble chart can visually convey block distribution (bd) values. These visualizations complement the findings obtained through SPSS analysis and present the information in a clear and understandable format. The analysis method, characterized by its multilayer and parametric structure, can be associated with Actor-Network Theory (ANT). By utilizing this method, the ongoing process of protocol analysis can gain deeper insights into the dynamics at play. Alongside the RQs, limitations and potentials for the Ostrakinda are discussed in comparison to games analyzed in the literature.

Ostrakinda is evaluated within the context of Mediterranean geography, similar to the Teos of Dionysos Game, which conveys archaeological knowledge through playable interactions (Varinlioglu et al., 2017), and the Anatolian Journey Game, which explores the Silk Road (Afshar et al., 2021). The ancient Mediterranean subject serves as the motivation for this study, given the richness of Turkey's cultural heritage. The pre-experiment results, which help identify the actual demands of students, further support the game's development.

Furthermore, various gamification strategies employed in the context of heritage can be compared, with a specific focus on cognitive aspects, interaction forms, target groups, and mediums. One recent study explores the use of sand-box serious games for heritage, emphasizing the development of critical reasoning skills, mental map generation, evaluation of alternatives, as well as matching and iconographic analysis (Bellotti et al., 2013). Another study introduces interactive tabletops as a generative design tool, combining virtual reality, motion capture, and shape grammars, to effectively transmit heritage knowledge to a non-specialist audience in an appealing and informal manner (Figueiredo et al., 2014). Lastly, an exemplified study proposes the implementation of an immersive augmented reality game set within an archaeological site, aiming to increase visitors' interest and facilitate the dissemination of heritage (Varinlioglu & Halici, 2019). Collectively, these studies provide support for the effectiveness of gamification in heritage education, as it offers an enjoyable, interactive, and engaging learning experience.

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GBL factors can be used to compare the proposed toolkit with other games, such as the educational puzzle game Slice It and the 3D role-playing history game Xiao-Mao (Shi & Shih, 2015). In Xiao-Mao, the score of narrative (factor 6) was higher (2.52) compared to Slice It! (4.22), while in Ostrakinda, the score was even higher (4.31). However, Slice It! scored higher (4.44) in terms of the game's challenge (item 8/a) compared to Xiao-Mao (3.80) and Ostrakinda (2.85). All three games performed well in terms of factor 1 (game goals), scoring above 4.20.

Feldt (1966) describes the most striking observation for the POGE as being completely engrossing, aligning with Csikszentmihalyi's flow theory. This theory suggests that when individuals are fully immersed in an activity, they experience heightened focus, enjoyment, and intrinsic motivation. Our study observed a higher level of involvement in gamified courses with Ostrakinda, particularly in group experiences. Similarly, Hart (2020) found that students preferred and were more engaged in gamified lectures compared to traditional courses.

The game Frequency 1550 (Admiraal et al., 2011), which focuses on medieval Amsterdam, facilitated a sense of flow among students, leading to increased engagement, collaborative learning, and active participation. Additionally, the factor of having fun (May, 1979) during gameplay was evident in Ostrakinda, with higher scores on items 3/c (4.43) and 9/a (4.49) on a 5-point Likert scale. Long-term findings since 2011, with 277 students experiencing 14 role-playing planning games, show an average enjoyment score of almost 8 and a usefulness rating of 7 on a scale from 0 to 10 (Stojanovski, 2020). Woodbury et al. (2001) provide tentative support for the role of play in early design education through engaging students in playful social settings using the Balance and Contrast game.

Design games can empower stakeholders during participatory process. User Game, Landscape Game, Technology Game, and The Scenario Game were utilized by Space Studio to explore various aspects of design and facilitate user-centred design (Brandt & Messeter, 2004). A role-play design game on senior housing named Character Game, aimed to creative thinking and empathic understanding, demonstrates various perceptions of a game as tools for designers, as a mindset for players, and as a structure for game designers (Vaajakallio & Mattelmäki, 2014). Perceiving of Ostrakinda by students also differentiated, such as an informal sesion within course, a socializing platform in group play, and a playful way for good use of time. The concept of players-as-producers emphasizes the learner's creative and constructive role, enhancing the flow experience and learning effects (Admiraal et al., 2011).

In games like Slum City (Silvestre, 2011) and ArchVille - CardboardCity (Peri, 2000), the use of tangible and digital toolkits is crucial. The advantages and limitations of these toolkits can be discussed in relation to the game objectives, considering the younger generation's interest and competence in digital tools. During the COVID-19 pandemic and earthquake crisis in Turkey, online workshops and courses highlight the distinct representation, scalability, interaction forms, and

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accessibility offered by digital toolkits. The tangible toolkit of Ostrakinda stands out as an efficient interaction environment. Both toolkits align with the game objectives, and ongoing research involves the design and testing of an augmented reality (AR) environment.

CONCLUSION

In this paper, we presented the findings of a long-term experimental study that focused on game-based learning (GBL) in design education. The objective of our study was to explore the effectiveness of teaching the morphologies of ancient Mediterranean cities using a toolkit we developed called Ostrakinda. By conducting a comprehensive analysis of the game process, outputs, and participants' feedback, we aimed to investigate the game's usability, critical components, and overall effectiveness within the GBL framework. Our study revealed that the game had a positive impact on learning outcomes.

The influences of play form and abstraction level highlighted the significance of game design in promoting flexibility, learning, interaction, and creativity among players. We evaluated the game's effectiveness based on GBL factors, and while we observed positive results for game goals, fantasy, narrative, and sociality, there was room for improvement in the challenge factor. To address this, we suggested refining scoring systems, diversifying game components, adjusting task difficulties, and improving the visibility of immediate decisions, all in line with the desired learning objectives and relative factors. To gain deeper insights into the dynamics of the game and visualize collective decisions, we employed the integration of OpenCV and PowerBI, which provided an advanced strategy for analyzing extensive game outputs. This analytical approach, characterized by its multilayer and parametric structure, allowed for a more comprehensive understanding of the game's outcomes.

In comparing Ostrakinda with similar games in the literature, we found that it received higher scores, particularly in narrative, fantasy, interaction, sociality, game goals, and mechanism, scoring above 4.20. This emphasizes the strengths of Ostrakinda as a playful learning tool and its alignment with other gamification strategies employed for conveying heritage knowledges. However, several areas for improvement were identified throughout our study. These include enhancing the measurability of the GBL model for design education, exploring the differentiation of game effects across students' levels in the architectural and urban design fields, comparing different forms of play (individual and collective), and mediums, as well as prioritizing specific learning outcomes. By addressing these suggestions outlined in the paper, Ostrakinda can evolve into a versatile and engaging educational tool, facilitating playful learning experiences and fostering a deeper understanding of ancient cities.

In conclusion, our study contributes valuable empirical findings and insights to the field of GBL by presenting the design, test, and analysis

DOI: 10.15320/ICONARP.2023.266

process in iterative action circles. By incorporating the suggested aspects for future research, as highlighted in the discussion section, Ostrakinda can further enhance its engagement, usefulness, and overall potential for effective learning.

ACKNOWLEDGEMENTS

We would like to thank all those who have participated to experimental studies for their valuable contribution. The authors would like to acknowledge that this paper is submitted in partial fulfilment of the requirements for the PhD degree at Yıldız Technical University (YTU). This work has been supported by Yildiz Technical University Scientific Research Projects Coordination Unit under project number FDK-2022-4867

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Resume

M. Ali Heyik, after graduating from the Department of Architecture in 2015, worked as an architect in several architectural offices in Istanbul, gaining experience through notable restoration projects in the Harem section of Topkapı Palace. In 2016, he was accepted into the Master's degree program in Architectural Design at Yıldız Technical University, where he successfully completed his studies in 2019, with a thesis entitled "Baths as Cultural Values and Mapping on Istanbul Baths." Since 2016, M. Ali Heyik has been actively engaged as a research assistant in the Department of Architecture at Yıldız Technical University, focusing on his ongoing PhD studies. His research endeavors encompass diverse fields, including design research, computational design, game-based learning, participatory design, collective intelligence, and ecosocial transition in coastal areas. M. Ali Heyik further enriched his academic journey by pursuing his doctoral research at UPM-Polytechnic University of Madrid as part of the Erasmus program between 2021 and 2022. Additionally, from 2022 to 2023, he conducted research at Granada University as part of the Tubitak 2214/A project.

Prof. Dr. Meral Erdoğan completed her undergraduate education in Architecture at İstanbul State Engineering and Architecture Academy (İDMMA) Architecture Department (İstanbul, 1977), her master's degree in İDMMA Architectural Design Master's Program (İstanbul, 1979), and her doctoral studies in the Architecture Program at İstanbul Technical University, Faculty of Science (İstanbul, 1986). In 1980, Prof. Dr. Meral Erdoğan started her teaching and research activities as a Research Assistant at İDMMA Kadıköy Faculty of Engineering and Architecture. She became an Associate Professor at Yıldız Technical University (YTU), Faculty of Architecture in 1995 and a Professor in 2015. From 1991 to 2022, she conducted education and research activities in the field of Design Computing, Design Research, and Design Technologies in the

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Assoc. Prof. Dr. Togan Tong graduated from Yıldız University, Faculty of Architecture, Department of Architecture in 1988 as an Architect. In 1990, he graduated from Yıldız Technical University, Faculty of Architecture, Department of Architecture, Building Science Graduate Program as a Master Architect. In 2000, he received his Ph.D. from Istanbul Technical University, Faculty of Architecture, Department of Architecture, Building Information Doctorate Program. He has been working as an Associate Professor at UAK since April 1, 2021. Togan Tong, who has been continuing his academic career at Yıldız Technical University, Faculty of Architecture, Department of Architecture, Department of Building Information since 1992, has been working as a faculty member in the Department of Architecture in the 2021-2022 Spring semester. Togan Tong, who is the director of Undergraduate, Postgraduate and Doctorate courses on subjects such as Computer Aided Design and Modeling, Digital Simulation Environments and Digital Architectural Thinking, Computational Design, Rule-Based Designs, Integrated Design Technologies, Building Information Technologies, conducts Computer Aided Design courses at different foundation universities. He continues his Digital Design Education Consultancy at the Istanbul Metropolitan Branch of the Chamber of Architects.

DOI: 10.15320/ICONARP.2023.266