# Motivating Visual Interpretations in Iconoscope: Designing a Game for Fostering Creativity

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## ABSTRACT

This paper introduces Iconoscope, a game aiming to foster the creativity of a young target audience in formal or informal educational settings. At the core of the Iconoscope design is the creative, playful interpretation of word-concepts via the construction of visual icons. In addition to that, the game rewards ambiguity via a scoring system which favors icons that dichotomize public opinion. The game is played by a group of players, with each player attempting to guess which of the concepts provided by the system is represented by each opponent's created icon. Through the social interaction that emerges, Iconoscope prompts co-creativity within a group of players; in addition, the game offers the potential of human-machine co-creativity via computer-generated suggestions to the player's icon. Experiments with early prototypes, described in this paper, provide insight into the design process and motivate certain decisions taken for the current version of Iconoscope which, at the time of writing, is being evaluated in selected schools in Greece, Austria and the United Kingdom.

## 1. INTRODUCTION

Arguably most, if not all, games have a great potential in enhancing the learning capacities and fostering the creativity of their players. From physical construction games such as *LEGO* to sandbox digital games such as *Minecraft* (Mojang 2011), many game design patterns revolve around construction, exploration and storytelling — often for the sake of the creative activity itself. The additions of competitive elements, winning conditions and a generally challenging experience to such highly creative activities "promote intrinsic satisfaction to players and offer opportunities for authentic learning" [15]. Given that creativity is increasingly being considered as an explicit educational objective within formal education [28, 7], games are an ideal vessel for fostering creativity within formal or informal educational settings. Commercial games such as *Minecraft* and *World of Warcraft* (Blizzard 2005) have already shown considerable capacity in their use in classrooms [32, 26]. However, designing a game with the explicit purpose of fostering creativity based on a theoretical framework of human creativity and a modern approach to the pedagogy of creativity comes with its own learning design advantages and, at the same time, game design challenges. This paper attempts to shed light on the design process of such a game.

The focus of this particular game design is creativity emerging during collaborative and communal activities (co-creativity in a group of players) while maintaining the role of the individual in the creative process. Creativity in this context is couched in two compatible theoretical frameworks which focus on different aspects of it, and which in turn inform different parts of the game design. On the one hand, creativity is viewed through the lens of *creative emotional reasoning* (CER) [29], a theory premised on creativity as an intervention to the player's thinking and creative process resulting in re-framing, i.e. the disruption of established routines and patterns. On the other hand, creativity is framed socially and ethically as *wise humanizing creativity* (WHC) [9] where a shared purpose within a collaborative creative space leads to dialog and the sharing of values and ownership — ultimately allowing young people to grow their identities "in a socially responsible, empathetic and communally informed way" [9]. Informed by the above, the educational scenarios in which the game will be used revolve around a pedagogical practice of (a) co-creative thinking via 'what if' questions, where learners move from 'what is' to new possibilities of 'what might be', (b) social engagement via flattened hierarchies and open dialog in the classroom, (c) impact awareness via the generation of ideas that matter to the community and (d) a wider picture of change via reflection during longer periods of co-creative activities [20].

Guided by the theoretical frameworks of CER and WHC and intended use in educational settings, this paper elaborates on the design of Iconoscope. Iconoscope is a game deployed on tablets which aims to foster the creativity of
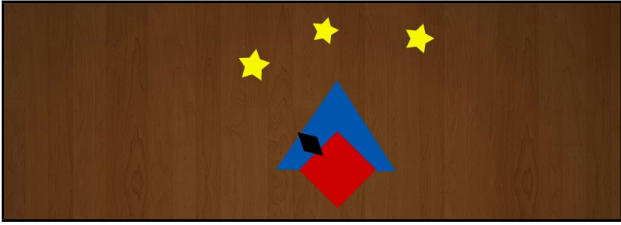
Figure 1: Example icon created via Iconoscope to represent the concept of *Modernization*.

its players. The inspiration behind Iconoscope comes primarily from non-digital construction and guessing games. Iconoscope motivates players to creatively interpret concepts (described linguistically) as icons (depicted visually) which convey the same message (see Fig. 1 for an example icon). According to creative emotional reasoning [29], the transformation of a concept from its semantic representation to its visual representation often requires lateral thinking [13] on the part of the interpreter. Lateral thinking is motivated further by the game's mechanics, which reward ambiguity in the construction of an icon, as well as the concepts included in Iconoscope which are indefinite and polysemous (e.g. "Tradition"). Moreover, Iconoscope is played in a social environment, with multiple players performing the same challenge and voting on each other's icons; the social interaction is enhanced by the portability of tablets which can be passed around the group or tilted so that all players can observe. The social dynamics are operationalized through Iconoscope's mechanics, as scoring is based on peer evaluation. Opponents attempt to guess the player's icon, passing each other's tablet in a round-robin fashion while doing so: the winning player's icons must dichotomize the opponents' opinions. The act of sharing both the physical tablet and the creations for peer evaluation drives home the message of collaborative creativity and shared ownership [8], and is likely to incite discussions between players during or after the process, allowing for an additional layer of reflection outside the game itself.

The mechanics of Iconoscope build upon the co-creation and sharing of icons between players in a social setting. Iconoscope also incorporates human-machine co-creation [34], as players can request computer-generated suggestions: players can choose to use the icon suggested by the system in place of their own, or continue working on their icon. These suggestions are created by algorithmic processes, targeting different design priorities. The suggestions are offered by "assistants" with names and portraits, which hint at individual personalities in tune with the algorithms which generate the suggestions. Similarly to interaction between players, interaction with the assistants is optional but can be another source of divergent thinking, whether the players accept the suggested icons to replace their own or not. Depending on the assistant, generated suggestions target visual novelty, similarity with a 'typical' icon for the specific concept or draw from past users' creations.

Iconoscope was developed under the C2Learn research project which aims to introduce an innovative digital gaming and social networking environment incorporating diverse tools, the use of which can foster co-creativity in learning processes in the context of both formal and informal educational settings. This happens in and around school communities covering a learner age spectrum from 10 to 24 years. C2Learn aims to shed new light on and test concrete ways in which our current understanding of creativity in education and creative thinking, on the one hand, and technology-enhanced learning tools and digital games, on the other hand, can be fruitfully combined to provide young learners and their teachers with innovative opportunities for creative learning. Along with Iconoscope, C2Learn incorporates several creativity games integrated into a social networking environment where players can share their own creations and appraise others' creations. As all player's icons created through Iconoscope are displayed as part of their creator's profile within the C2Learn social environment, there is further potential for sharing knowledge and inspiring others well beyond the playtime of Iconoscope.

## 2. BACKGROUND

The design of Iconoscope is informed by theoretical frameworks of creativity which have been adapted for educational settings, and draws inspiration from existing games and activities which have fostered the creativity of younger audiences for years. This section provides a brief overview of the grounding and inspirations of Iconoscope.

### 2.1 Theories on Creativity

The topic of creativity has always fascinated humanity at large, and from this fascination numerous theories and definitions of creativity have emerged over the centuries. Creativity theories have been formed around different academic fields and perspectives, such as philosophy (e.g [33]), neuroscience (e.g. [12]) or psychology (e.g. [31]). Since a core design goal of Iconoscope is to foster creativity in young players, it is necessary to have a practical but theoretically sound basis for understanding of creativity. A general overview of research on creativity is provided below, followed by the core principles of creativity targeted by the Iconoscope game.

Creativity has often been attributed to great thinkers and inventors and was enshrined within an almost mystical halo, as an activity of the gods in us [27]. Recent years have seen philosophy and cognitive sciences attempt a more methodical, scientific approach at understanding the process of being creative. With a better insight in the creative process, creativity is no longer considered a unique privilege of reclusive geniuses (who undertake what is referred to as big-c creativity) but is considered under the prism of every-day, social forms of creativity [17, 11] (referred to as little-c creativity). Distinctions such as the one between little-c and big-c creativity abound in creativity literature (e.g. passive and active creativity [4], exploratory, combinatorial and transformational creativity [5]) and characterize the process of being creative.

Another topic in the discourse of creativity concerns the artifacts resulting from creative processes. Whether creative artifacts are restricted to works of art or include scientific discoveries has caused considerable controversy [18]; however, this distinction is not productive as both artistic and scientific creativity can be seen as problem-solving [6], while works of art can be discoverable from a Platonic point of view [19]. Another characterization of creative artifacts is that they must be both novel and valuable [5]; a novel artifact without value, i.e. "original nonsense" [18], would not be deemed creative. Novelty and value of creative artifacts re-

main ambiguous terms and are open to discussion in creativity theories; novelty has been considered under the prism of psychological novelty (P-creativity) where an idea is new to the person that produced it while not necessarily new to society in general, and historical novelty (H-creativity) where the idea has never occurred in history before [5]. Value has also been difficult to define, due both to the subjective evaluations of creative artifacts and to the ethico-cultural prisms through which value can be perceived, for instance considering destructive yet novel ideas [16].

The framing of creativity for the context of Iconoscope (and the C2Learn research project in general) is built around *creative emotional reasoning* and *wise humanizing creativity*; a brief overview of these frameworks is provided below.

Within the context of creative emotional reasoning theory, the creative act is understood as an intervention that results in re-framing [29]. A frame is understood as a routine for performing tasks, a prism through which the world is understood, a pattern of associations between facts, emotions or actions. Intervention, in this case, comes from outside a particular frame and serves to disrupt established routines of that frame. The intervention presumes agency from an agent interacting with that frame; while the agent often is presumed to be human, agency of this sort can be ascribed to e.g. a computer system or a natural disaster. Disruption of a pattern of thought (a frame) is a core component of creative emotional reasoning theory. A disruption opens up a lateral path, defined as a cognitive process that promotes deep exploration of a possibility space, whilst satisfying stated (or implicit) conditions, i.e. under constraints. Within Iconoscope, such a disruption aims to change individual players' or the group's associations among words (e.g. those in the concept triplet) or between words and icons (achieving diagrammatic lateral thinking [34]). Disruptions in Iconoscope can originate from the game design (e.g. unlikely triplets of concepts), from fellow players during the scoring phase (e.g. unexpectedly inaccurate guesses), or from generated alternatives to the player's icon (provided by computational assistants). These disruptions aim to trigger re-framing of associations and routines in individual players or the group, likely leading to P-creativity [5] (i.e. ideas new to the player or the group).

Wise humanizing creativity revolves around the concept of change guided by compassion and reference to shared values [9]. Wisdom in this context builds upon [3], which defines "wisdom as expert knowledge and judgment about important, difficult and uncertain questions associated with the meaning and conduct of life". According to [3], emotions and values have an important role "in the acquisition and expression of wisdom", with people higher in wisdom-related knowledge showing a larger concern on the welfare of others compared to their own happiness. Wise humanizing creativity investigates frameworks of creativity "guided by compassion, empathy, alleviation of difficulty, and some reference to a shared value system" [8]; it moves away from marketized, individualized creativity and attempts to balance communal, collaborative and individual creativity [8]. Iconoscope similarly attempts to balance individual creativity, as each player constructs an icon individually, with collaborative creativity when players take turns reviewing and evaluating each other's icons; communal creativity can be achieved via the shared ownership of both the physical tablets (which are passed around during peer evaluation) and of the individu-

ally created icons which leads to a shared visual vocabulary of imagistic interpretations of concepts. In the context of wisdom as per the above description, Iconoscope provides the difficult ethico-cultural questions through the concept triplets and the scenario presentation (described in Section 3.1), which implicitly contextualize the users' goals in icon creation and frame the discussion which follows the Iconoscope playthrough.

## 2.2 Games which Foster Creativity

Many digital games, analog games, toys and outdoors activities rely — explicitly or implicitly — on the creativity of their players. This section will identify some of these games and toys which share the design patterns (i.e. rewarding ambiguity) and gameplay (i.e. diagram creation) of Iconoscope.

Construction games have a long history both in digital media and in physical play. In many cases such games do not have an explicit goal other than construction for its own sake: toys such as the *LEGO* bricks or *Tangram* are exemplars of this philosophy. Players of *Tangram* are provided with seven flat shapes (five triangles and two parallelograms), usually black, which they can use to construct a specific shape such as a dog or a monk. Players of *LEGO* are provided with numerous multicolored bricks, which they can use to construct three-dimensional structures such as houses and cars. In both cases, the nature of the building blocks (black triangles or rectangular bricks) limits how closely the constructed artifact matches what it tries to represent. By focusing on the spatial arrangement of components, their shape, size and color, the player provides sufficient visual cues for the artifact to be recognizable. Freeform digital construction games such as *Minecraft* largely follow the patterns of *LEGO* play, which has substantiated the argument for their use in educational settings [32]. A common pattern in construction games is the creation of structure and meaning from basic, tangible components. Iconoscope uses this pattern by allowing players to move colorful, abstract shapes freely on a canvas (see Section 3.2), and expressly motivates the creation of meaning through the concept triplets (see Section 3.1). Unlike freeform construction games which provide no extrinsic reward for construction (other than the satisfaction of construction itself), Iconoscope uses a scoring mechanism on the player's creations (see Section 3.3). While extrinsic rewards such as points can increase motivation on a specific task (based on operant conditioning), it has been argued that they lower the potential for fostering creativity [1]. However, the score of Iconoscope is not provided by an external system (e.g. an algorithm) but is based on peer evaluation. Scores in Iconoscope not only motivate competition for the highest score among players in the same game, but also necessitate that players consider their colleagues' perception and interpretive abilities. The combination of competition and empathy, which arises from the introduction of the scoring system, gives rise to a social form of play and promotes discussion during play but also the formation of shared values and ownership after the game is finished.

A final example of creativity apps without end-goals is *Creatorverse* (Linden Labs, 2012), which ceased to be developed and supported in 2014. *Creatorverse* is played on tablets and allows users to create images using basic shapes and freeform line-drawing. Taking advantage of the touch interface of tablets, users can add animations, conditions and other interactive elements to their drawings, allowing

them to create simple games such as pinball or maze games. The creations can be shared with other *Creatorverse* users, and each user can edit another's creation. The tactile experience of dragging and dropping shapes via touch in *Creatorverse* hints at physical interactions with construction games such as *LEGO*, while the digital medium is advantageous for allowing animations and conditions but also the sharing of creations. Iconoscope follows similar patterns, using the touch-based functionalities of tablets for providing an intuitive, simple interface for moving, rotating and scaling shapes, while the digital nature of the created icons allow the game to provide real-time suggestions from computational assistants as well as share the user's creations in a social environment once the game is finished.

Beyond freeform construction for its own sake, certain creativity games are centered around competitive play with rules and winning conditions. *Pictionary* (Angel Games 1985) relies on one player's ability to depict a word drawn from a card deck in a way that will make members of that player's team guess the word correctly. The team with most correct guesses after several rounds of gameplay wins. Since each team is allocated the same time period per round, guessing the word quickly will result in a higher score within each round. While *Pictionary* relies on the diagrammatic representation of words, other games such as *Taboo* (Hasbro 1989) and charades operate on the same general concept (guessing the correct word or phrase) while the player relies on verbal descriptions and pantomime, respectively, to provide sufficient clues to the team. All of these games purposefully restrict the expressivity of the player: *Pictionary* allows a single pencil and no speech or signaling, *Taboo* forbids using a set of related or obvious words when describing the target word, and charades do not allow any speech. These restrictions are in place to force the players to creatively interpret the concept they need to convey relying on rarely used methods of communication, thus disrupting their typical practices and way of thinking. As a competitive creativity game, Iconoscope similarly uses a time constraint on gameplay but adapts the scoring system in order to reward ambiguous interpretations rather than accurate depictions of concepts (which is implicitly rewarded in *Pictionary*).

Finally, a large inspiration for Iconoscope with regard to the goal of rewarding ambiguity is the card game *Dixit* (Libellud, 2008). *Dixit* is played by 3 to 6 players, with each player having a hidden hand of six cards with evocative, colorful images. In *Dixit*, one player is the "storyteller" each turn and sets the challenge to other players: the challenge is a sentence of one or more words, and all players (including the storyteller) secretly choose one image among those in their cards which best matches the storyteller's sentence. All cards are collected, shuffled, and shown to the players: the players (excluding the storyteller) must vote for which of the images belongs to the storyteller. If all players guess the storyteller's image correctly or if no player guesses it, the storyteller receives no points and everyone else receives 2 points. Otherwise, the storyteller receives 3 points and everyone who guessed correctly also receives 3 points. Players beside the storyteller whose image was voted receive one point for each vote. *Dixit* builds upon the ambiguity of the images shown on its cards, and explicitly rewards ambiguity in its scoring mechanisms and winning conditions. Iconoscope similarly rewards ambiguous creations; instead of allowing a storyteller to provide the concept (or *Dixit*'s

"sentence"), however, Iconoscope provides several pre-made concepts and allows users to choose from them. While creativity in *Dixit* is found in the storyteller's invented sentence and the players' choices among pre-made drawings on their cards, creativity in Iconoscope is found in each player's choice among pre-made concepts and each player's invented drawing. Iconoscope's flat hierarchy among players (due to the absence of a storyteller) also requires a different scoring mechanism than *Dixit*, as discussed in Section 3.3.

# 3. ICONOSCOPE DESIGN

Iconoscope is a digital tablet-based game intended to infuse creativity to the learning process, either as a trigger at the beginning of a learning unit or as part of a toolbox used to explore a given theme. A typical game session of Iconoscope is described below.

A group of Iconoscope players, each starting the game on their own tablet, are presented with a theme and three concepts related to the theme; concept triplets are presented in Section 3.1. Each player secretly chooses one of these concepts. Each player begins creating an icon using the drawing interface described in Section 3.2; the icon consists of several simple, colored shapes. After a period of time has passed, the game is over and the players show their icon to the group for the purposes of voting. Passing the tablets around, other players (opponents) take turns observing the icon and choosing which of the three initial concepts it represents. Once each player has voted for each other player's icon (and thus each tablet reached the icon's creator), the voting phase is complete. Based on the number of opponents and their votes, a score is given to each player's icon. Scoring is described in Section 3.3; in short, the scoring system rewards ambiguous icons which are however specific enough to be correctly guessed by at least one opponent.

## 3.1 Concept Triplets

At the start of each Iconoscope session, the system presents three different concepts to the player, who has to choose one of them to depict as an icon. The chosen concept is always shown as the player draws (see Fig. 2, top left corner). At the end of the drawing period, all opponents must guess which of the three concepts is represented by the player's icon. In an Iconoscope session, all players receive the same three concepts, but choose individually — and in secret — the one to depict. The concepts included in Iconoscope are chosen by experts in pedagogy, in order to be appropriate for the target age and the curriculum of the educational settings where Iconoscope will be used. Currently, concept triplets are grouped along overarching *themes* such as "cruelty against animals" and "dangerous situations". Each concept triplet constitutes a *challenge*; one or more challenges of Iconoscope or other C2Learn games constitute a broader unit of inquiry (*scenario*). Each scenario is accompanied by a short text, which is presented via the social environment of C2Learn before starting any challenge within that scenario: this text provides the context of the challenge and sets a topic for debate before or after the challenges are played.

As a concrete example, one of the scenarios under the theme "cruelty against animals" is accompanied with this text: "How can we save circus animals from cruelty? This kind of entertainment is still offering people pleasure and jobs!". The two Iconoscope challenges of this scenario use the following concept triplets: (a) "Coercion", "Punishment",
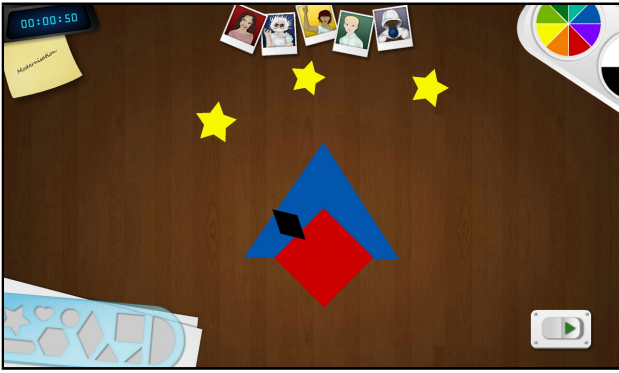
Figure 2: The drawing interface of Iconoscope: the possible shapes are at the bottom left of the screen and the possible colors at the top right. Assistants are shown at top center and the chosen concept is shown as a post-it note at top left.

"Pain", and (b) "Tradition", "Bullfights", "Modernization". The link between the scenario's text and the concepts is quite obvious; the concepts themselves are thematically related but in different ways for each challenge. In the first triplet, the concepts are semantically very close (although not synonymous), and they would be challenging for players to clearly depict as icons — although this likely increases the chances of resulting icons being ambiguous. In the second triplet, the concepts are not directly related (although tradition and modernization could be seen as opposites) unless the context provided by the scenario's text is taken into account. Even so, drawing icons that can be misconstrued as other concepts in the second triplet poses a different problem than in the first triplet, as players need to think of common patterns (visual or semantic) shared between two or more of these largely dissimilar concepts.

## 3.2 Drawing Interface

The drawing interface of Iconoscope allows players to construct icons that represent a concept; icons are composed of one or more simple shapes of different colors and sizes. Visually, the drawing interface is reminiscent of a children's physical drawing table, with stencils for creating shapes, watercolor palettes for adding color to shapes and post-it notes for reminding the player of the concept they have chosen to represent (see Fig. 2). The shapes used to represent icons are mostly basic geometric shapes (squares, rhombi, circles, hexagons, triangles); due to their emotional resonance, a few less abstract shapes were also included (star, heart). The simplicity of the provided shapes necessitates that players combine them in meaningful ways, but also that they abstract away from simply pictorial representations — which is enhanced by the use of abstract concepts in the game. Each game session of Iconoscope is timed, and all players need to have finished their icon within a specific time period, at which point voting starts; a clock with remaining time is shown on the drawing interface (top left corner of Fig. 2). The time limit to icon drawing is sufficient for numerous shapes to be added to the canvas (thus avoiding very simple icons) but is not sufficient for icons to become too elaborate and "busy" in terms of composing shapes (as this would detract from the goal of abstract, ambiguous icons). Similarly the range of colors for shapes is purposefully small, although

all primary and secondary colors are available, along with black and white. The few colors make the interface less cluttered, speed up drawing, and enforce the creative color combinations to convey meaning and emotional resonance.

## 3.3 Scoring

As noted in Section 2.2, Iconoscope incorporates the notion of scoring (and winning) in a similar fashion to *Pictionary* or charades, rather than taking the stance of freeform construction games which assume construction is a reward in itself. Determining the winner of a game session in Iconoscope is based on peer evaluation, with each other player attempting to guess which of the three concepts the player's icon represents. In Iconoscope a created icon has achieved its purpose if it has communicated the underlying concept to some but not all other players. The scoring principle is somewhat similar to that of *Dixit*, as it rewards ambiguity. Since there is no storyteller and no competition between icons, however, another scoring system had to be devised — especially to resolve ties. The current scoring method uses a point system: the player with the most points wins. If all opponents guess the correct concept depicted by the icon, the player gets 0 points; similarly, if no opponent guesses the correct concept, the player again gets 0 points. In all other cases, the player gets a score $S = min(C, O - C)$ where $O$ the number of opponents (one less than the number of players) and $C$ the number of correct guesses. For 4-player games, the above formula rewards a score of 1 for one and two correct guesses; for 5-player games, the above formula rewards a score of 1 for one or three correct guesses and 2 for two correct and two incorrect guesses. The scoring system therefore rewards icons which dichotomize public opinion. However this scoring system evidently is likely to result in many ties, especially in games with an even number of players. To determine a winner when two or more players have the highest score, an extra point is awarded to players with a higher number of correct guesses than other tying players. If there is still a tie, an additional point is rewarded to tying players for each unique wrong guess; a player wins if opponents disagree more on which concept is represented. Despite the extra tie-breaking conditions, ties can still occur; in this case, no-one wins and the winner can be determined in the next game round.

## 4. COMPUTATIONAL SUGGESTIONS

In conjunction to the social aspect of creativity facilitated through the peer evaluation and sharing of created icons, Iconoscope also aims to incorporate human-machine co-creation as part of the creative process [25]. This is accomplished through computer-generated suggestions, which players can use to replace their own icon design during the course of gameplay. The suggestions are provided, at the player's request, from a creative "assistant", the portrait of which is shown on the drawing interface. While players are using the drawing interface to create their icons, they can select one of the five assistants; when they do so, a screen with up to four suggested icons appears (see Fig. 4) and the player can select one of the suggestions to replace their current design or can reject all of them and resume creating their icon. In line with recent findings on interface considerations of AI-assisted design [22], the computational input is entirely optional and can be overridden; even in cases where suggestions are rejected, however, it is expected that

Figure 3: The graphical representation of assistants, which provide suggestions to Iconoscope users.

the stimulus may subconsciously inform the user's current or future designs. Since all of the suggestions offer alternative icons to what the player is currently drawing, they act as disruptors to the patterns of the player's current art style and the semantic links their icons are built on [29, 34]. Even if the players discard the assistants' suggestions, this conscious decision requires that they reflect on the diagrammatic reasoning going into their current icon; the suggested icons are inserted into their working memory, which is critical for creative thinking [12] "as it allows for the retention of relevant knowledge when problem solving" [24].

Iconoscope offers a set of assistants with distinct visual representations (portraits of Fig. 3) and names; this makes them more characterful, and offers a certain insight on their priorities when generating suggestions. The assistants' names and an overview of their generative processes follow:

**The Mad Scientist** proposes icons that quickly diverge from the user's icon and from other generated icons.

**The Wise Oracle** proposes high-scoring icons from previous players of Iconoscope.

**Typical Tom** uses conservative diagrammatic typicality, proposing icons similar to a pre-defined typical set.

**Progressive Petra** is the opposite of Typical Tom and employs progressive diagrammatic typicality, proposing icons dissimilar from the pre-defined typical set.

**Chaotic Kate** offers random permutations of the user's drawn icon.

Apart from the Wise Oracle (which presents past user-created icons unchanged), the assistants present variations of the user's currently drawn icon. These variations are created by applying *mutation* genetic operators on the user's own sketch. A mutation can move, rotate, scale or recolor one or more existing shapes, change the shape type of one or more existing shapes (e.g. from square to circle) or clone an existing shape, creating a second shape with the same properties (position, color, shape type). For Chaotic Kate, each suggestion comes from applying several random mutations to the user's icon. For Progressive Petra, Typical Tom and the Mad Scientist, suggestions are created via *artificial evolution*. In artificial evolution, the most promising individuals in a population (based on some *fitness* heuristic) are selected and create offspring [14]; this is repeated a number of times, creating generations of individuals. In the case of Iconoscope, a population consists of 10 permutations of the user's icon; this initial population evolves according to an evolutionary strategy [14], where the fittest half of the population is mutated and replaces the least fit half. After
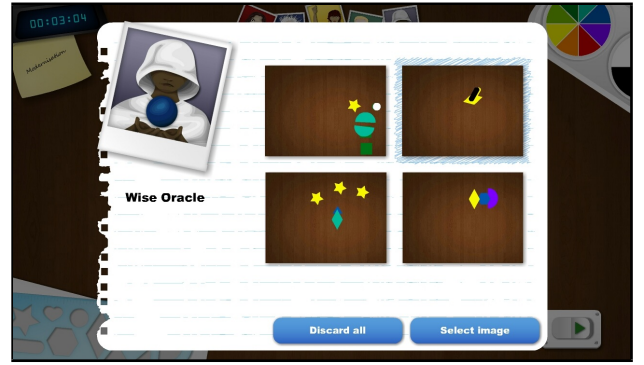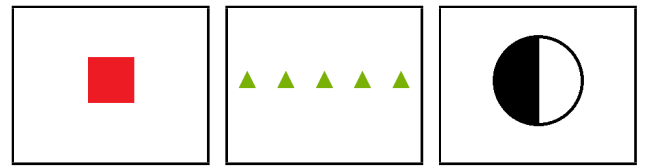


Figure 4: Suggestions offered by the Wise Oracle, shown after the user clicks on her icon. The user can optionally select one of the suggestions to replace their current icon.



(a) Bullfights    (b) Forest    (c) Discord

Figure 5: Indicative 'typical' icons for concepts shown in the captions. These typical icons were authored by the game's designers. Typical Tom targets similarity of suggestions with the typical icon for this concept while Progressive Petra targets difference from the typical icon.

10 generations, the four fittest suggestions in the population are chosen to be displayed on the drawing interface.

When selecting which icon is fittest for Progressive Petra, Typical Tom and the Mad Scientist, different heuristics are used depending on the assistant. The Mad Scientist deems fittest those icons which are visually different from those in the population (of current and previous generations); the algorithm follows the principles of novelty search [21], as it uses an archive of novel individuals and measures an evolving icon's fitness as the difference from its five closest neighbors. For Progressive Petra and Typical Tom, the fittest individuals are those that are the most and least different, respectively, from a pre-defined typical icon for the chosen concept (see Fig. 5). Each concept has a typical icon in its database, provided by the game's designers: the algorithm measures an evolving icon's fitness as its difference from the typical icon, with Typical Tom attempting to minimize that difference and Progressive Petra attempting to maximize it.

It should be noted that the fitness heuristics of Progressive Petra, Typical Tom and the Mad Scientist all use a notion of visual *difference*. As icons created via Iconoscope hinge on other player's diagrammatic reasoning [10, 30], either visual (i.e. what real-world object they depict) or analogical (i.e. what message they symbolize), generated suggestions target diagrammatic lateral thinking to break the players' preconceptions of what meaningful icons can be drawn. Towards that end, several measures of visual difference are encoded into the system, inspired by theories on visual perception [2] (grouping, balance and color). The current version of Iconoscope uses the following heuristics for difference:

**Color difference** which is high if colors in one icon do not exist in any shape of the other icon.

**Shape difference** which is high if shape types in one icon do not exist in the other icon.

**Shape & Color difference** which is low if shapes have the same color and shape type in both icons; it is high if colors or shapes are not shared between icons.

**Position difference** which is high if one icon's shapes (regardless of color or shape type) are not in the same positions as the other icon's shapes.

**Grouping difference** which is high if one icon's shapes are positioned near each other (grouped together) while the other icon's shapes are dispersed.

## 5. EARLY PROTOTYPES

In order to appraise the educational and entertainment potential of Iconoscope, several prototypes of different degrees of fidelity with the final application were tested.

An early experiment made use of the drawing interface of *Microsoft Word* for the creation of appropriate icons. This experiment was performed by pedagogy experts over Skype, with different icons (saved in *Microsoft Word* format) communicated and judged asynchronously over e-mail. This early, low-fidelity experiment had two primary purposes: (a) to devise concepts appropriate for use in educational scenarios which appeal to the target audience (young learners and their teachers) and (b) to evaluate whether the simple geometrical shapes proposed for Iconoscope (e.g. squares, triangles, circles) were sufficient to represent such concepts. With regard to concepts used, the feedback was that using three concepts worked well, although a larger number of concepts could eliminate the efficiency of randomly choosing a concept when guessing other players' icons. To counter the efficiency of random guesswork, the scoring system favors concepts with more rather than fewer correct guesses (in cases where guesses are not evenly split). Regarding making icons using simple shapes, players reported that the limited shape list and modifiers (scaling, rotating, etc.) forced them to compose meaning from building blocks rather than via drawing. Indicatively, Fig. 6 shows the icons of the four players for the concept triplet: *Friendship*, *Sharing* and *Difference*. Observing all players' icons across several game sessions and taking their feedback into account, several conclusions can be drawn. The different players followed different strategies both when choosing the concept and when drawing the icon. Some players started by choosing two concepts, one to represent and one to introduce ambiguity towards by looking for visual links between the two; others decided in advance on the concept and its image and tried to compose that image with the shapes at hand, while others started to play with the shapes and decided afterwards which concept suits the nascent icon better. Players reported that constructing visual representations that juxtaposed concepts (e.g. when introducing ambiguity towards other concepts beside their chosen one) led them to see affinities among concepts that they had not noticed before. In terms of the representation of concepts as icons, players saw an individual "art style" emerging for each of them as they continued playing. Some players used as few and as simple shapes as possible, often relying on color to convey meaning; one player used several
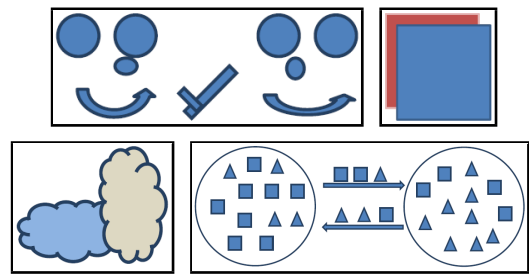


Figure 6: Four icons created by different pedagogy experts, via the drawing inteface of *Microsoft Word*. The icons represent concepts among *Friendship*, *Sharing* and *Difference*.

simple shapes to represent more complex images such as the faces in Fig. 6, while another player used large numbers of shapes to create complex diagrams. Finally, as the participants of this experiment played continuously for six sessions (six concept triplets), they reported that continued interaction with the game acted as a learning experience with one icon design informing the next, reusing the same shape in different sessions and evolving its capacity. Coupled with the development of an individual visual style for icons, these findings were promising for the development of the first digital prototype of Iconoscope.

A second iteration of the Iconoscope design was accompanied with a digital prototype written in javascript (see Fig. 7). The purpose of this browser-based version of Iconoscope was to (a) test the user interface and the user's interaction (i.e. how intuitive and controllable mouse gestures are for the purpose of creating icons) and (b) to finalize the scoring mechanism. Towards these objectives, a playtest took place at the Institute of Digital Games among members of the group with various degrees of game design experience. The concepts used were chosen from the lists provided by the pedagogy experts during the earlier experiment. Unlike the first experiment, players were in the same room and able to interact; the social aspect and discussions over the drawn icons contributed significantly to the entertainment value of gameplay. Similar to the first experiment, however, different players found different visual styles and strategies for conveying the concept to a few opponents, e.g. via abstract visuals with few shapes (example in Fig. 7) as well as via the extensive use of more symbolic shapes such as hearts, clouds and crescent moons. Players voted by passing notes on paper, which were collected by a game master overviewing the experiment. No winner was announced during the playtest; instead, as a follow-up to the process, the best player was decided in a brainstorming session and a scoring strategy was adapted in order for the score based on votes to match the group's qualitative consensus.

These early experiments informed the final design of Iconoscope as detailed in Section 3. Currently Iconoscope is being piloted in selected schools in Greece, Austria and the United Kingdom with students from upper elementary through high school level. These pilots will evaluate the appeal of the final drawing interface described in Section 3.2 and the chosen concept triplets to a younger audience. Moreover, the pilots will test how young learners interact with the assistants and how the computer-generated suggestions affect the player's creative thinking and lateral paths [34].
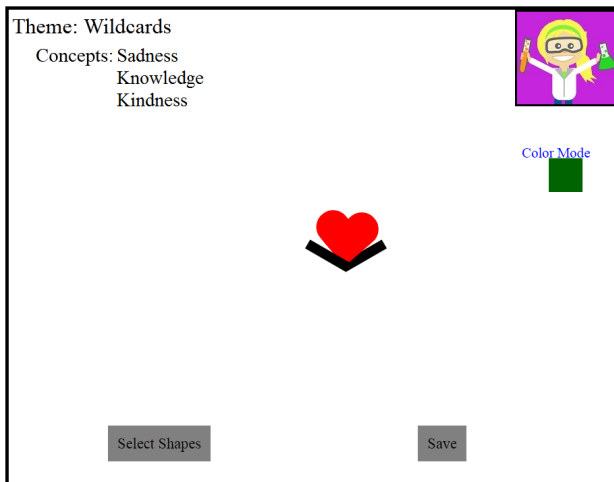
Figure 7: The browser-based prototype used for the second iteration of Iconoscope design. The icon was created during the playtest among game designers.

## 6. DISCUSSION

Iconoscope was designed to motivate the creative interpretation of semantics (concepts) to visuals (icons), interweaved with competitive gameplay based on social interactions. The simple shapes and limited color pallette make Iconoscope more of a puzzle game than a drawing application, although the interface similarities with the latter lower the barrier of entry for the younger target audience. The scoring system, while not as straightforward as e.g. that of *Pictionary*, pushes towards icons which do not faithfully represent the concept at hand; the concept triplets themselves reinforce this as they are thematically similar and semantically vague. The incorporation of computer-generated suggestions offers additional options to players: the different assistants with their distinct personalities and priorities when creating suggestions can act as a creative stimulus when a player is stuck.

Early experiments with Iconoscope in different stages of the design process and with prototypes of varying degrees of fidelity with the final game showed that different players found different approaches in choosing concepts as well as in visualizing them as icons. Moreover, the limited shapes and colors made gameplay faster, while the social component of observing each other's creations and voting influences both the fun of gameplay and, according to the theory of wise humanizing creativity [9], promotes community and shared values. These early experiments were performed on low-fidelity prototypes, without computational suggestions and with academically-minded adults (involved in the project) as players. It should not be understated, therefore, that the final design of Iconoscope — with all its components in place — remains to be tested with its intended target audience in selected schools in Greece, Austria, and the United Kingdom as well as through large scale on-line competitions.

Apart from possible design additions following the feedback from pilots in schools, several steps are considered for improving the game experience of Iconoscope. A potential improvement pertains to the voting and scoring process, in a way that improves their potential for dialog and reflection. Currently voting is assumed to be secret, while the complexity of the scoring system can also lead to some obscu-

rity regarding who is the winner, or why. This process can be made more transparent, e.g. by letting players see their opponent's guesses after the game is completed, or by presenting which rules were applied when calculating the score (via a points breakdown interface component). A more intelligible end-game can lead to a better understanding of both the game's mechanics but also of the other players' reasoning; this can motivate reflection and dialog, leading to the disruption of typical visual patterns and the development of shared values within the group.

Another area of improvement is the impact of computational suggestions, which can be reinforced in two ways: by improving the quality of the generated suggestions and by increasing the "visibility" of the suggestions during gameplay. For the former, the generative algorithms could be improved to minimize the creation of unwanted suggestions, e.g. via more and better heuristics of visual difference or via constraints on the number and connectedness of shapes. For the latter, the current version of Iconoscope requires that users select the assistant, wait for a short time, review the suggestions, and apply or reject them; an alternative could be to create and present suggestions directly on the drawing interface, while players are creating their own icon. This approach was used in Sentient Sketchbook [23] and allows users to constantly survey what the computer is suggesting without making a deliberate choice to "ask for help" (as it may be perceived); even if the players do not use the generated suggestion, they are likely to be influenced by it in their own drawing and style. The proposed real-time display of suggestions, however, will require more space dedicated to assistants which may require a redesign of the interface since the tablets on which Iconoscope is played have a limited screen size.

## 7. CONCLUSION

This paper described the design principles behind Iconoscope, a game aimed at fostering the creativity of its players. Iconoscope motivates such creativity in the clever, ambiguous rendition of semantically indeterminate concepts as simple, visual icons. The voting mechanic motivates social interaction and reflection on each player's visual style and interpretation of the concept, while the scoring system necessitates that players think outside the box [13] when creating polysemous icons. As an additional stimulus, Iconoscope includes computer-generated suggestions as alternatives to the user's own icon; these suggestions are provided by several "assistants" with distinct portraits and generative methods. Early experiments demonstrated the impact of the different design decisions, and current pilots in schools will evaluate how the target audience interacts with the game, highlighting potential areas for improvement.

## 8. ACKNOWLEDGEMENTS

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