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# An introduction to ChemiKami AR

Tengjia Zuo<sup>1</sup>[0000-0002-2103-1899], Erik D. van der Spek<sup>1</sup> [0000-0001-8885-0373], Max V. Birk<sup>1</sup>  
[0000-0002-1490-2086] and Jun Hu<sup>1</sup> [0000-0003-2714-6264]

<sup>1</sup> Systemic Change, Industrial Design, Eindhoven University of Technology, The Netherlands  
t.zuo@tue.nl

**Abstract.** ChemiKami is an Augmented Reality card game aiming to introduce chemical elements to students before they are formally being taught chemistry. We designed an avatar representation for each chemical element as well as an application card related to each element. Players can complete the game task by putting the correctly matched avatar card and application card together and having them scanned by an AR device. This game presents several applications of chemical elements in a fantasy setting. Using the idea of employing endogenous fantasy in AR game-based learning, we aim to explore the effect of fantasy on the player's motivation and working memory. As virtual and game-based learning becomes a leading trend of education, research using ChemiKamiAR helps designers identify the role of fantasy in AR game-based learning.

**Keywords:** Fantasy play, game-based learning, working memory, Augmented Reality, Serious Games.

## 1 The design of ChemiKamiAR

ChemiKami is a portmanteau of two words. Chemi represents this game's learning goal—chemistry, while Kami is a Japanese word meaning spirits or avatars with supernatural powers [1]. We designed the AR-game-based learning application ChemiKami AR to help and encourage beginners to learn chemistry and scrutinize the effects of fantasy elements such as anthropomorphic representations on motivation and learning. Each chemical element is designed into an avatar, with different characterizations, voices, and magical powers, embellishing the element's daily application with fantastical representations. Traditionally, learning chemistry, especially memorizing the names of the chemical elements and their associated traits from the Periodic Table of the Elements [2] is difficult and requires a lot of effort [3]. With the idea of enhancing one's working memory on chemical elements, we implement anthropomorphisms into our design in a fantastical way. Previous research indicates that anthropomorphisms create more emotional and cognitive interests among players [4, 5]. We will research

the effect of fantasy on the player experience and learning effects through design research in future work.

### 1.1 Mechanics and systems

The game is developed using Unity 3D 2020.2.7F1, Vuforia Engine 9.7. The application needs to be installed on an Android phone with camera access and sound on, and a set of cards needs to be printed out to be able to play.

Players will be introduced to two kinds of cards: an Element card and an Application card. Both cards can be scanned by a phone individually or side by side, and show a 3D overlay with an animation. The application card is about a real-life application domain that requires one of the chemical elements. For example, it could show a sign without any color, which then needs an element that often exists in pigment (Figure 1, left). Scanning the Application card alone, players would see a scene of daily life without the existence of a certain chemical element (in this case a sign that is not very visible). The Element card is designed with a picture of the avatar representing the element, the name, and a short description of that chemical element. Scanning the Element card alone, players will see an avatar representing the element, introducing themselves with the description printed on the card. By reading or listening to that description, players can find hints for pairing the Element card and the Application card, e.g., Bismuth is an element in the Bismuth yellow pigment (Figure 1, Right). Reading this description, players may find this chemical element can play a role in the card of “the sign with no color.”



**Fig. 1.** The application card (left) and the role card (right), which are available in both English and Chinese



**Fig. 2.** Animation under AR device when two cards are paired correctly

After pairing the right combination, players can have both cards scanned by the AR camera. If correctly paired cards are scanned simultaneously, the avatar will cast the “magic of chemistry” and complete the task on the Application card. For example, when cards in Figure 1 are correctly paired, the Bismuth avatar will cast a magic spell to make the sign noticeable with a bright yellow color. Then the man who is about to fall notices the sign and watches out for the slippery ground (Figure 2).

## 1.2 Game design theories

There are few game design theories we apply in ChemiKami AR. Using the idea of fantasy play [6], we turn knowledge of facts into thematic fantasy and the traditional memorizing processing into playing and making believe [7]. Fantasy play can positively affect social competence like peer skill achievement and affective role play[8, 9]. With the affordance of Augmented Reality, this game tries to create a context of what Stapleton defines as Mixed-fantasy [10]. In his Mixed-fantasy continuum, AR games enable a lasting impression of the gameplay experience. Such experiences should persist if players interact with only the physical object without AR because their imagination plays a leading role. We are curious if such Mixed-fantasy will influence players’ motivation and learning outcomes.

The emotional design principles were introduced for designing ChemiKami AR. Mayer et al. coined emotional design as “redesigning the graphic in a multi-media based learning to enhance the level of personification and visual appeal of the learning content.” In ChemiKami AR, we design each chemical element into an avatar, with different voices, magical powers and characterizations. Aiming to increase learners’ motivation, this game has the potential to improve their learning outcomes through appropriate cognitive processing in learning [4].

## 2 Interaction and Social learning

### 2.1 Single-player and multiple players

ChemiKamiAR can be played single-player or multi-player. For a single-player, there is no tension of competition. It takes three steps to complete each task, as shown in figure 3. The key to completing the game task is to find the right connection between chemical elements and their application.



Fig. 3. Three steps of play

The multiplayer mechanics are generally the same as in single-player, with the addition of competition and cooperation. A stack of Element cards with their backside facing up will be placed on the center of the table. In addition, each player holds a set of Application cards. For each turn, one player starts the game by flipping one Element card. Once the game starts, players need to find the correct Application card pairing from their decks as soon as possible and place them next to the Element card in the middle of the table. The one who has both cards scanned under (an) AR camera (s) first, triggering the successful narrative, will win this turn and take the Element card. Additionally, there could always be cooperation with more players on both sides. For example, while one player is holding a phone and scanning cards, others can look for cards, solving the puzzle together.



Fig. 4. Social learning and play

## 2.2 Interaction design

We emphasize tangible interaction in game design since prior research indicates that tangible interactions may offer a more enjoyable experience than screen touch for the user via a sequence of intuitive and natural interactions[11]. Focusing the players' attention on tangible interaction with cards makes it easier for them to play in the absence of AR. Enabling play alternately with and without AR may foster children's imagination through mixed-fantasy [10], therefore possibly enhancing their memorization of chemical elements.

## 2.3 Social learning

We introduce competition and cooperation through multiplayer game modes. Previous research indicates competition will increase players' immersion [12], while cooperation will encourage communication and social connection in gameplay [13]. Both aspects have the potential to improve players' play and learning motivation[14]. Additionally, the tangible part of ChemiKami AR helps build the social connection around this game. Players can collect and exchange cards they gain from the social gameplay mode. Research indicates collecting objects makes players enjoy the gameplay [15]. Furthermore, research shows that collecting and exchanging cards increases children's learning motivation and can improve learning outcomes [16].

### 3 Future work and possible contribution

There is frequently a discussion about serious game design and how to design a motivating and practical learning experience [17–19]. With ChemiKami AR, we would like to explore the potential effect of Mixed-fantasy, and how the fantastical anthropomorphisms and emotional design influence motivation and learning in an AR game context. In addition, we are curious to see if this game would have a lasting effect after gameplay so that players can be motivated to memorize more through imagination without the help of AR. We are furthermore curious to see if other game principles like social play, competition and collection would play a positive role in this game.

Virtual learning has become a leading solution for geography and time issues in education [20]. Learning outcomes and motivation have become a major concern when the physical and social connection is often absent in most virtual learning [21]. We hope the design of ChemiKami AR would benefit students and educators who try to seek motivational ways of introducing chemistry knowledge. Additionally, we hope game design researchers would benefit from strategies of employing mixed fantasy in serious game design, which we would figure out using ChemiKami AR in our future research.

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