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# Towards Identifying Augmented Reality Unique Attributes to Facilitate Chemistry Learning

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**Abstract.** Augmented Reality (AR) applications have the potential to improve students' Chemistry learning performance. By identifying the unique features and affordances of this technology, we can design more effective tools to facilitate the learning process of abstract concepts. We developed Periodic Fable in the Wild, an AR serious game as an instrument to conduct design-based research. The game aims to facilitate the learning of abstract concepts related to the Periodic Table by children (9 to 13 years old). We intend to optimize our game by continuing our research with our target audience, analysing their feedback, making refinements and continuing testing.

**Keywords:** Augmented Reality · Serious games · Spatial skills · Chemistry.

## 1 Introduction

Children, as young as nine years old, have already a perception of Chemistry as complex, not so attractive, less relevant to everyday life and a challenging domain [1, 2]. Some of the factors that contribute to a negative perception of Chemistry are that it demands imagination, since there is no visible or physical referent; translating 2D information into 3D mental models can lead to cognitive overload and students with low spatial skills struggle with mental models [2].

Augmented Reality (AR) uniqueness of superimposing digital information within the real environment provides children's opportunities to:

1. Engage with educational content in digital format [3] while relating them to the actual physical world [4].
2. Provide visualization of abstract and complex concepts through animations, 3D modeling and other digital information.
3. Develop broader spatial skills by using activities with 3D objects (virtual or physical), providing an effective context for teaching [5].

By developing an AR serious game to conduct design-based research, we intend to identify AR features and affordances towards facilitating the learning of abstract concepts in Chemistry. We also intend to change the negative perspective of this domain by using game design elements to engage children toward the learning content.

## 2 Periodic Fable in the Wild Systems Designs

Periodic Fable (PF) in the Wild is an AR serious game targeting 9 to 13-year-old children, designed to teach them basic chemistry concepts of the Periodic Table of Elements in formal and non-formal educational settings. The game's sub-theme evolves around the chemical composition of some products and substances (verified and validated by a chemistry teacher and a chemistry researcher). The AR game uses a marker-based system that operates with images/patterns (scan by the mobile device) to trigger the upload of virtual information (in our case, tridimensional models, animations, text, sound and a 2D minigame). The app was developed for android mobile devices using ARCore SDK for Unity 3D.

PF in the Wild was also developed with the aim to integrate every day routine products, that children are accustomed to (water bottle, bleach, batteries, balloons), as part of the game-play mechanics. The game's situated learning approach allows our target group to gain scientific knowledge about the chemical compounds that form the products. The goal is to achieve this by interacting with physical objects, AR technology and collaborating with other colleagues. PF in the Wild contributes to the learning process by creating meaningful connections between the content and the context.

The game starts with a tutorial that guides the user through the different game components:

1. The gathering of chemical atoms composing the product in question. The atoms are collected by scanning markers allocated in the products displayed on shelves (see Fig.1 - number 1). All the collected atoms are displayed afterward on a 2D grid (see Fig.1 - number 2). The application indicates the player when it has collected enough atoms by blocking the capture button. An animation of a character that represents an element with such atoms will also be showcase (see Fig.1 - number 1).
2. Reconstruction of chemical composition of the selected product by combining the atoms identified in the screen's chemical structures (using a mini word puzzle kind of game). The collected atoms' icons are aligned on a simple grid and need to be connected by the participant's tip of the finger from one atom to the next. The player is guided in the sliding action by the chemical formula, which shows the order of the atoms, and it is displayed on the right side of the screen (see Fig.1 - number 2).
3. Anchoring the AR visualization in the real world. The player has to use the device camera to scan and recognize a pattern in the real-world player surrounding. The AR application will build the AR experience around that loca-

- tion and allow the visualization of the tridimensional AR compound/molecular structure created by the player (see Fig.1 - number 3).
- Conclusion of the game experience. Congratulation message and player score display appear after the AR experience. The player's score is calculated by the time they spend on each activity within the game (see Fig.1 - number 4).
  - Game reward. A Reward- Selfie screen is displayed at the end of the experience inviting the player to take a picture with all the game characters to share with family and friends (see Fig.1 - number 5).



**Fig. 1.** PF in the Wild game flow

To get an overall understanding of the game, we conducted a pilot study with five participants (three female and two male). Children with ages ranging from

11 to 13 played the game for about 10 minutes. Some of the comments that we gather from post-game experience interviews point to the learning potential of the game "I think this is good for learning since I need to use the right compound to keep going"; usability "it is easy and good for learning"; the repetitiveness of the game mechanics "mini-game is too repetitive." We also asked the players to think aloud and took observation notes. In this note, we observed one of the players seems lost in collecting the elements and manifested frustration by saying, "I forgot which compound I was trying to form." Nevertheless, when asked: Will you play again? all of the participants answered "yes".

### 3 Conclusion and Future Work

We developed an AR serious game to evaluate the features and affordance of the technology towards facilitating the learning of abstract concepts of the Periodic Table. After a preliminary pilot study with the five children, we identify game-play elements that need refinements, such as the game's repetitiveness, which we plan to address by incorporating new elements, like animations and visual feedback between each task. Also as to better guide the user towards the compound that needs to be created at the different stages of the game, we will implement the display of UI with an images of the compounds structure until the tasks are accomplished (see Fig.1, number 2 - right corner). Nevertheless, the overall players' assessment was positive and the comments oversee the app's potential as a tool to engage children with the content knowledge, in order to validate the game, further research is needed. This research's next step is concept and usability testing of the AR serious game with larger sample groups in formal and non-formal settings.

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