Learning Elements and Organic Molecular Structure through Augmented and Virtual Realities

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Introduction

In the process of science learning, both instruction and learning are quite challenging since many concepts were abstract and complex. This is especially true in chemistry where the knowledge construction and development of microscopic particles often rely on learners' visual abilities in traversing between two-dimensional representations and three-dimensional objects, or learning about these relationships through assistive tools. Therefore, if learners lacked the three-dimensional visualization ability or appropriate assistive tools when they are learning important chemistry concepts, they could easily come across setbacks, which could result in learning difficulties. Conversely, should they possess good spatial abilities or receive instructions with appropriate assistive tools, students' abilities and performance in traversing between two-dimensional representations and three-dimensional objects could be improved.

Visualization

In many studies, it was shown that one's visualized representation and visualization abilities would influence the complex spatial imaginative ability required for student learning. For example, Nakhleh & Postek (2008) stated that external visual and audio representations can help students learn about limited reagent. These representations include: 1. Real-time chemical reaction (macroscopic understanding), 2. Computer simulated reaction (microscopic level understanding), 3. Pictorial representation (symbols), and 4. Textual representation during problem solving. Furthermore, Gilbert (2008) also pointed out that chemistry learning involves micro, sub-micro, symbolic, and their inter-relationships. Based on Gilbert's perspective, models can be external (e.g. something that can be touched) and internal (e.g. individual mentality) representations. Visualization is the giving of meaning to either of these representations. In chemistry, molecular structure and property, especially the complex organic molecular structure, are often found to be difficult concepts to grasp, and therefore, developing appropriate learning assistive tools can decrease students' cognitive loads.

■ Augmented Reality and Virtual Reality

Augmented Reality (AR) and Virtual Reality (VR) products have experienced exponential growth in commercial and gaming industries. However, for educational products, there is still a need for more research and development. According to existing literature, AR features the following characteristics: 1. It enables 3-D perspectives, 2. It allows ubiquitous, collaborative, and situated learning, 3. It provides learners a sense of presence, immediacy, and immersion, 4. It can visualize concepts or events that cannot be seen, 5. It bridges formal learning with informal learning. These characteristics provide students with the opportunities in engagement, contextualized, and authenticity learnings (Wu, et al., 2013). As for VR, in a research study that conducted a metaanalysis of 13 journal articles on VR-based instruction, it was found that gaming, simulation, and virtual world all have positive influences on learning, and student achievements from gaming-styled VR instruction is higher than those of simulations and virtual world. Another interesting find was that students in solo-game play outperformed those in grouped game play (Merchant, et al., 2014).

The current paper mainly wishes to introduce two apps that can be used in chemistry instruction. One is a deck of organic molecular structure cards that combined AR and VR, and the other is compound cards that combined Group 1A and 7A atomic structures with AR.

■ Introduction to the Organic Molecular Structure App

The *Organic Molecule AR/VR* cards the current research developed is the only application in the app market that features both learning and game play. It is available with three different decks of cards. The manual and QR-code download link for the app can be found in the cards; or one can also search for Molecules 1 AR/VR, Molecules 2 AR/VR & Molecules 3 AR/VR in Apple App Store or Google Play in Android devices. Information can also be found on the website of CCS Located in Taipei (http://www.chemistry.org.tw/app_download.php).

The *Organic Molecule AR/VR* cards were designed mainly with the organic compounds found in high school curriculum. The three decks of cards are based on the functional groups. The first deck is consisted of hydrocarbons. The second alcohol, ether, and ketone. The third, acid, ester, amine, and amide. The chosen organic compounds in each deck are mainly isomers with the same carbon number. For example, with a carbon number of 4, there are 1-butene, cis-2-butene, trans-2-

butene, and 2-methylpropene (as shown in Figure 1); for homologues in the same functional group, there are formic acid, acetic acid, propionic acid, butyric acid, and valeric acid (as shown in Figure 2).

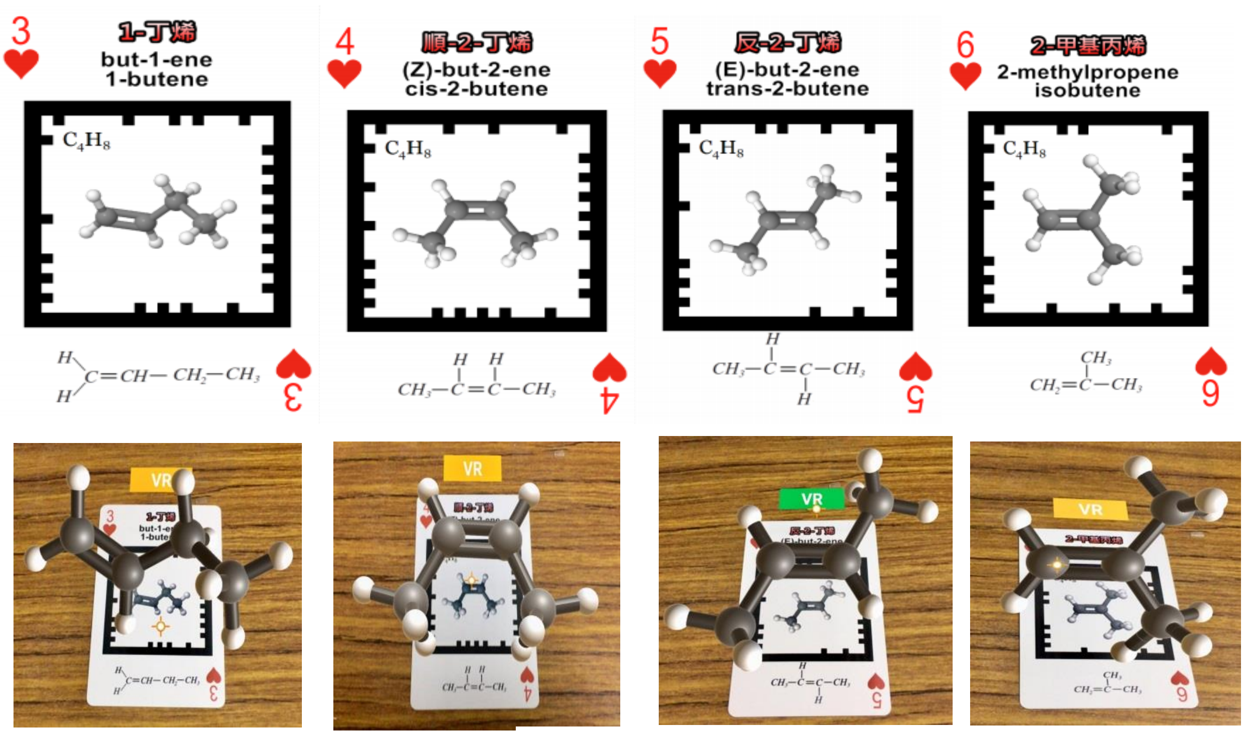

Figure 1 Isomers

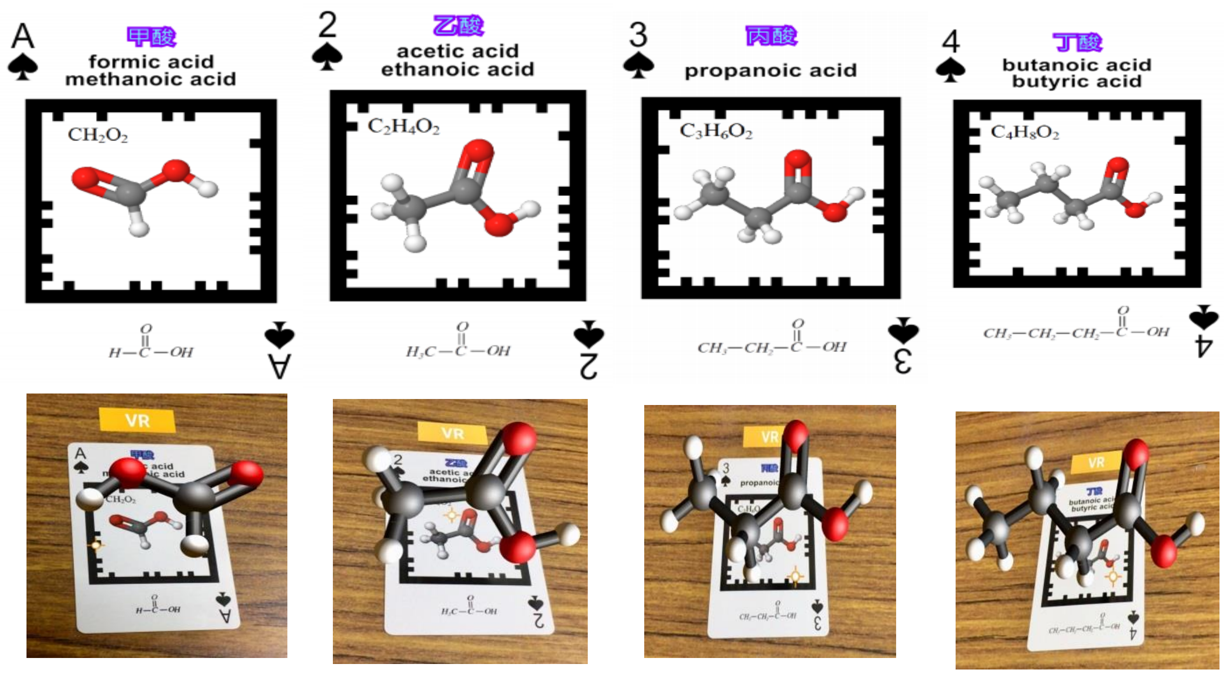

Figure 2 Homologues of the same functional group

In addition to showing organic molecules having three-dimensional structures, the main concepts the cards intend to convey also includes isomers and homologues. Through these cards, it is hoped that students will develop a deeper understanding of chemical equations, symbols, and conversion between 2D and 3D structures.

The app for *Organic Molecule AR/VR* cards, with its AR technology, can assist teachers to better explain the 3D structure and characteristics of organic molecules (see Figure 3). Students can also manipulate the angles of the molecules through touchscreen or joystick to better view the structure and characteristics of every section of the molecule. Furthermore, with its VR technology, students can be assessed on what they have previously learned in class regarding molecular structures through a virtual computer game scenario, where they have to accomplish a mission of finding the structures of organic molecules (see Figure 4). This scenario features gaming elements such as time limit for the mission (see Figure 5), rewards and punishment during game play (see Figure 6 and 7), and feedback at the end of the mission (see Figure 8). It is hoped education through entertainment would make learning organic molecular structure no longer a dull chore. Instead, it would become a medium that not only binds game and science learning, but also enhance learning and exchange between teachers and students.

Figure 3 Molecular Structure AR mode

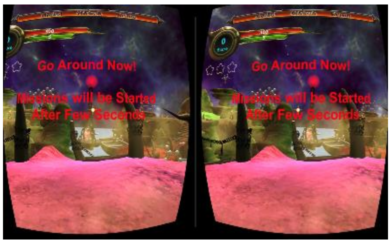

Figure 4 VR Game Play Scenario

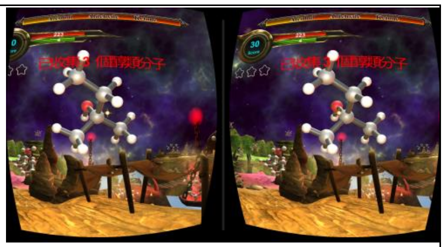

Figure 5 The mission to gather alcoholic molecules

Figure 6 Monster appears if the wrong molecule was selected

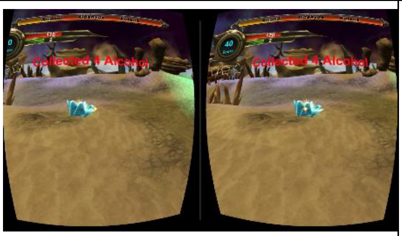

Figure 7 Gathering jewels to extend time

Figure 8 Feedback when the mission is accomplished

The app developed by the Graduate Institute of Science Education, NTNU, has three modes of game play (see Figure 9), all of them need to be played in conjunction with specific cards. Each mode includes two modules. The first module enables the player to observe the 3D structure and characteristics of every organic molecule through the AR module of the software. The second is an assessment of learning outcome in a gaming scenario. This assessment can only be accessed by selecting a VR label on the screen, which can only be reached through the card's AR mode screen once the player has gained sufficient knowledge about each type of molecules.

Figure 9 Selection for the three modes of game play

■ Instructional Activity Design

On the application of the cards and the app, there are three main approaches:

I. Direct Observation: Ask the students to directly scan the cards with the app and observe how the structure of the 3D molecule shown on the mobile device is different from those shown on the card. Allow the students to try to rotate the structure of the 3D molecular model to a perspective where it would look the same as those shown on the card or books, and take a screenshot and upload it to the cloud storage the instructor had prepared. Finally, project the screenshots students have taken for discussion. It is hoped that students would learn how the 3D organic molecular structure is related to the structural formula. In this process, the instructor may also select specific cards (such as finding isomers or homologues from the same functional group) and ask students to point out the relative spatial position of atoms.

II. Learning sheets: Instructors may utilize designs similar to those from the table below to conduct their instructional activity (see Figures 10a and 10b), and ask the students to fill in the chemical equations and name the compounds. The learning sheet can be downloaded from the dedicated app instructional material page on the CCS Located in Taipei website (http://www.chemistry.org.tw/app_download.php#pagefive).

Instrctors may reorganize the learning sheet (see Figure 10a & 10b) according to the organic chemistry content he/she instends to teach. Students may use the app to scan the learning sheet, observe the 3D structures and write down their structural formulae. Or, the instructor may simply list the compounds' IUPAC naming and its related codes, such as pentane, 2-methylbutane, 2,2-dimethylpropane, and ask the students to write down their corresponding structural formulae, followed by a grouped discussion on the relationship between the IUPAC naming and the structural formulae.

C_4H_{10}	C_5H_{12}	C_5H_{12}	C_5H_{12}
2-甲基丙烷	戊烷	2-甲基丁烷	2,2-二甲基丙烷
2-methylpropane	pentane	2-methylbutane	2,2-dimethylpropane

C_6H_{14}	C_6H_{14}	C_6H_{14}	C_6H_{14}
己烷	2-甲基戊烷	3-甲基戊烷	2,2-二甲基丁烷
hexane	2-methylpentane	3-methylpentane	2,2-dimethylbutane

Figure 10a Original Learning Sheet

填入分子式			
畫出結構式			
命名			

Figure 10b Adjusted Learning Sheet

III. Board Game: The first deck of cards: Hydrocarbons, can be used as a card-based board game. Instruction can be found online at: https://goo.gl/E13011.

■ Brief Introduction to the 1A and 7A Groups in the Periodic Table

Our research team has developed another app called *AR_Element(1A, 7A)* in addition to *Organic Molecule AR/VR*. The app introduces the structures and symbols of the 1A and 7A elements through AR; students can observe their atomic models through the app and the cards. They can also try to form molecular models by combining two cards (e.g., by combining the cards of H and Br, the app will display the molecular model of HBr). The instructor may allow students to choose different elements' cards to form various different molecular models in accordance to the needs of the course. Students may then observe the different ways molecular models can be displayed (e.g., molecular model, Lewis electron models, ball-and-stick model, Van der Waals radius model etc.). This app utilizes emerging technology to enhance students' learning motivation, provides students with ways to get to know about the structure and representation of materials, and enables the formation of the correct conceptual understanding on material structure through discussions amongst students.

Figures 11 to 20 describe ways to get the app, the cards, and instruction for the operation of the app.

Google Play Figure 11 Search for AR_Element(1A,7A) at Google Play	Figure 12 Download App and click to start
 Figure 13 Select the lower left corner icon to download cards once the app has been started	 Figure 14 The frontside of the card is the information on 1A,7A atoms

Figure 15 App Interface Instruction

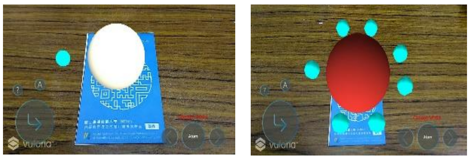

Figure 16 Using the app to scan the back of card would render the AR model of the atom.

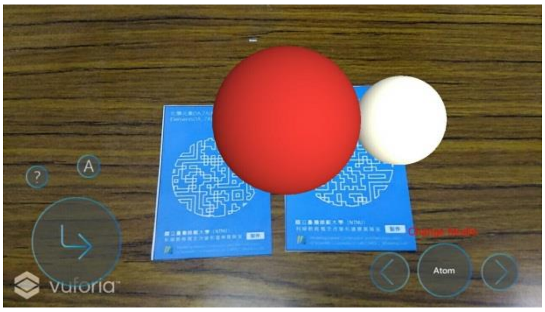

Figure 17 By placing two cards that can be combined next to each other, the combined molecular model would be shown

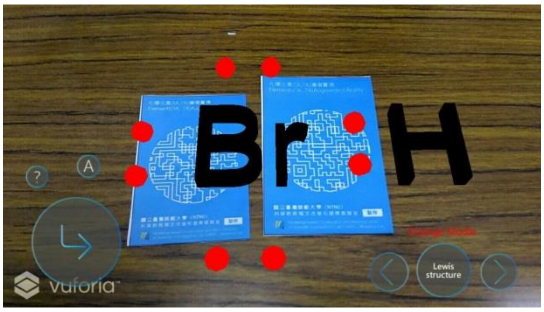

Figure 18 Switching to the Lewis Model

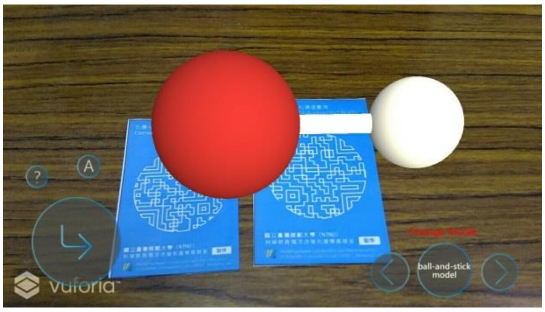

Figure 19 Switching to the ball-and-stick model

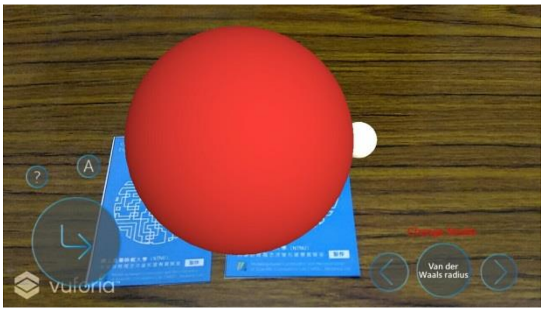

Figure 20 Switching to the Van der Waals model

■ Conclusion

The 12-year compulsory education has put a great emphasis on the core and cross-discipline concepts. In the field of natural sciences, the “composition and structure of materials” is one of the basic concepts among the core and cross-discipline concepts. As a response to this, for the first time, the natural sciences curriculum has included the “concept of particles” among the contents for elementary stage learning. At the high school level, the cultivation of microscopic views, abstract thinking, and model construction abilities have also been greatly increased. In addition to raising students’ spatial visualization abilities and cultivating and linking chemistry knowledge on 2D and 3D representations, introducing AR and VR assistive tools at this time can also make chemistry learning more fun for students, achieving the goal of education as entertainment. We believe there will be a lot of room for development for this kind fo learning style in the future.

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