USING EDUCATIONAL STRATEGIES AND TECHNIQUES BASED ON INTERACTIVE CARTOONS, ANIMATIONS AND 3D VISUALIZATIONS TO REBUILD SCIENTIFIC KNOWLEDGE IN CHEMISTRY IN HIGHER EDUCATION

K. Dalacosta[1,2], E.A. Pavlatou[1]

[1]School of Chemical Engineering, National Technical University of Athens (GREECE)
[2]State Scholarships Foundation (IKY) (GREECE)

Abstract

Cartoons constitute a form of amplification through simplification that can be used in many ways to heighten the message the educators want to pass in-class or core concept use. The effectiveness of interactive cartoons usage enhances students' concentration on a science topic which is being discussed in class, and overall is a basic element of the learning process and in creating an active learning environment. Also, animations allow students to engage in three learning styles simultaneously – visual, auditory and kinesthetic – which increases their knowledge comprehension. However, the use of animation, such as in 3D dimension or in simple simulation, it has provided visual cues for students to enhance their cognitive processing. So, animation can reinforce the process of visualization as an effective cognitive strategy to enhance conceptual understanding. In parallel 3D visualizations that runs in all browsers, without the adequate plugins or programs by giving the students the freedom to rotate them or change their sizes, observe the kind of information that they want and have difficulty to optimize or understand it, could provide a smart didactic tool in the academic unity. To this end "new" multidimensional teaching techniques must be adapted to attract undergraduate students interest to study basic concepts of Chemistry, which in turn reconstruct their scientific knowledge and overcome the difficulties they face in that demanding learning process. Concepts such as atomic orbitals, hybridization, chemical bonds, state of matter, intermolecular forces, some of them that they have being taught in secondary education, create them misconceptions. For that reason, digital material enriched with cartoons, animation, 3D and 2D graphics and digital educational games, was created. Combinations with 3D visualizations (in the case of atomic orbitals i.e. px, py, pz or hybrid orbitals sp, sp^2, sp^3) assisted with cartoons (in a form of avatar Curie – Einstein - Darwin or as supplementary tool), educational games i.e. with flipping cards that demand the cross-matching of the right concept with the adequate graphic, animations with cartoons aided to explain the hybridization of carbon C etc., where constructed from scratch. In this digital material we focused on the main presumption that the undergraduate students must have the ability to intervene through the controlled movement and also choose windows - android, computer or tablet with the one that are familiar too. With the proper use of educational strategies and techniques of this specifically designed education material in Chemistry, we aiming to increase the active participation of students in the learning process, enabling them to control the pace and the way of learning.

Keywords: Cartoons, animations, 3D visualizations, chemistry, higher education.

1 INTRODUCTION

Cartoons is an art form, developed and transformed to an important visual language, which basically affects human emotions and transmits messages using symbols and images. The cartoons are familiar to the students and have the ability to attract their attention through humour, stereotypes symbols or figures and encourage them to focus on the main scientific idea presented in the image. In the educational community they have also been shown to be effective communication channels for science education in many disciplines areas as cartoons have been used widely at many levels and in many areas, with growing evidence of their effectiveness [1, 2]. Many researchers exemplified the use of cartoons as a mean for assessment based on the fact as they are a highly effective way of probing students' science conceptions and, crucially, their misconceptions upon obscured science concepts or as a mean for evaluation of their scientific cognition [3, 4]. Also the findings of Köse [5] showed that students' knowledge, understanding and attitude of biology was positively changed on the unit of endocrine system with the use of cartoons. Moreover Kumasaki et al., validated the efficacy of manga

ISBN: 978-84-09-05948-5

comics for chemical safety education to students in three universities as they found that they provide a helpful tool for learning, in a potential hazardous environment that need certain rules to be applied [6].

Cartoons and humour can even be preferred for conceptualizing and making sense of concepts accepted as tricky and abstract [7]. This is evident in chemistry that has been deemed to be a challenging subject by many chemistry learners primarily due to the complexity of there being three 'levels' at which the learning of chemistry operates, the microscopic level of atomic and molecular species and their interactions, the macroscopic level, and the representational level of symbols and equations.

Also in science education, several studies focused on how students make sense of what they see in animations and how this information positively enhances students' understanding of atomic level events [8]. Animation was found to be able to reinforce the process of visualisation as an effective cognitive strategy to enhance conceptual understanding [9]. Mayer and Moreno [10] further elaborated that animations are effective as they are designed in ways that promote the human cognitive process – to have corresponding pictorial and verbal (narrations) representations in the human memory at the same time. Viewing animations help students to form a more detailed mental model of the event, and help students connect to concrete models. However, even though students may try to adapt what they see in the animations, they typically retain imperfect understanding. In essence, students need cognitive skills that are necessary for understanding the purpose of the animation to help them become visually literate of the information portrayed, and how his/her scientific knowledge is affected.

In higher education the interpretation and visualization of chemistry concepts from the sub microscopic level, can be extremely challenging for students and can lead to a range of conceptual (misconceptions), visualization, and reasoning difficulties that can impact negatively on their understanding of molecular models. It is obvious 3D visualizations are useful "tools" that aid students to achieve the appropriate cognitive level that permits the understanding of demanding cognitive concepts and rebuild their scientific knowledge. The importance of 3D visualizations is confirmed by the findings of Maier and Klinker [11], who evaluated an augmented reality-based 3D user interface and how the 3D understanding of molecular chemistry is enhanced and Barrett.et al, [12], who studied in organic chemistry the effectiveness of virtual and concrete models for aligning and producing multiple representations in stereochemistry, using college students without prior domain knowledge.

2 EDUCATIONAL WEBSITE BASED ON INTERACTIVE CARTOONS, ANIMATIONS AND 3D VISUALIZATIONS

In order to rebuild undergraduate students' scientific knowledge in chemistry, an educational website based on interactive cartoons, animations and 3D visualizations was constructed, that runs in most browsers without any plugins. Educational interactive cartoons (as agents or supplementary tool) were constructed, in which by performing functions such as representing, emphasizing, highlighting, showing, describing chemistry concepts or phenomena accompanied with narration, aided the improvement of students learning process. Also 3D visualizations where also developed, where students were capable to intervene through the controlled movement (by choosing the size or rotate the 3D graphic as he/she preferred) and also to select windows or android to watch them. Specifically, three js code was used that also underpinned the achievement of the desired aesthetic level of the 3D visualizations, in terms of their illumination and transparency. Also in the homepage was added js code, which recognizes the user's device automatically (tablet, computer), runs in (windows, android), and in the case of the resolution (greater or less than 800) automatically forwards the user to the corresponding version that has been created for the device and the operating system he/she uses.

The website is composed of different types of educational learning objects such as representations, animations, learning activities i.e. drag and drop type and educational games i.e. game with matching flipping cards. All the types of learning activities are guided by cartoons and contains animations or 3D visualizations serving certain didactical purposes. The learning objects are characterized as useful tools in the hands of the teacher/educator as they are flexible enough to be used wisely in higher education, as basic parts of educational strategies and techniques aiming to improve students' scientific knowledge.

2.1 Presentations

Visual representations usually utilize the symbolic method. A typical example is the case, where we can describe the bonds at Boron trifluoride, BF_3, according with the valence bond theory, based that the molecular geometry is the one that gives the model VSEPR. More analytically first we write the Lewis type, then we apply the model VSEPR for the atom of boron. Surrounding the atom of boron are electron pairs which we expect to have a planar triangular arrangement. The sp^2 hybridized orbitals have planar triangular arrangement. Then the valence electrons are placed in the hybridized orbitals. Finally three fluoride atoms approach the hybridized orbitals of boron. The 2p orbitals (one of each fluorine atom) held by single electrons overlap with each of the sp^2 orbitals of the boron, thereby forming three covalent bonds B-F. Note that one of the 2p boron orbits remains unhybridized and electron vacuum. This orbital is oriented vertically to the plane of the molecule. All the above mentioned steps are summarized in the following orbital diagrams, in “Fig 1”.

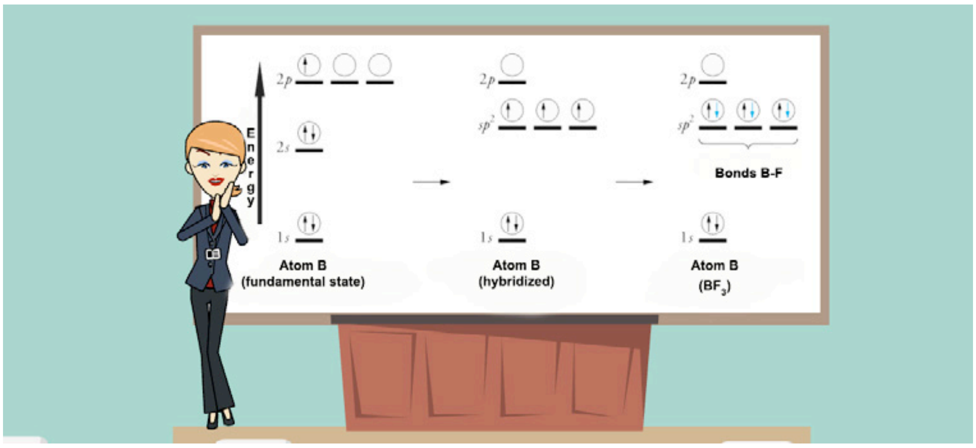

Figure 1: The formation of bonds in boron trifluoride, BF_3 guided by cartoon.

Additionally sometimes presentations utilize 3D visualizations, describing concepts from the sub microscopic level depending on students’ perception. Perceptual symbols can also arise from introspection, the internal activities of the brain such as cognitive operations (compare, search, transform, and elaborate). Perceptual symbols of introspection are particularly important to the understanding of abstract concepts arising from the submicrospic level such as the “atomic orbitals”. In the case of p atomic orbitals, which are shown in “Fig 2”, the student has the capability to rotate the 3D visualizations of atomic orbitals in every axis he/she prefers and study them thoroughly.

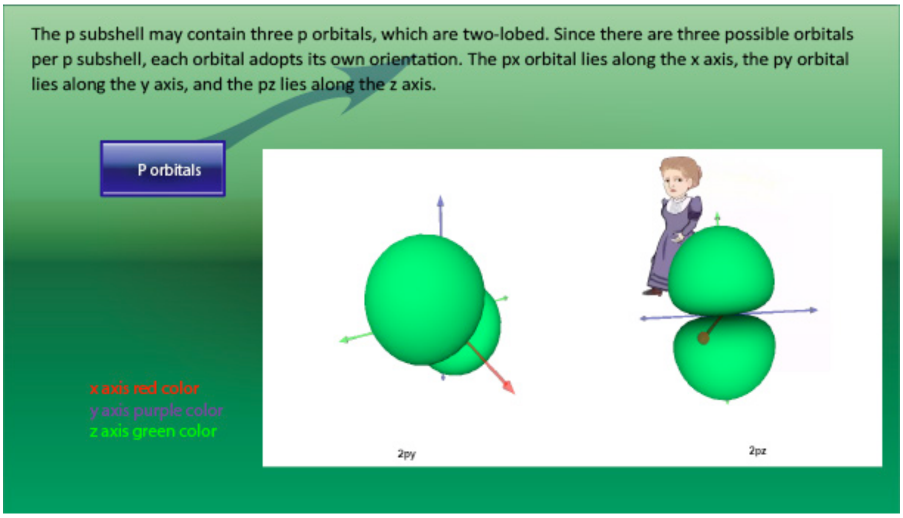

Figure 2: Atomic orbitals (2py – 2pz) with the supplementary text and guidance of Curie.

2.2 Animations

Animations provides visual cues that facilitate the learning process of concepts related to the microcosm. For istance in the hybridised of carbon, in the case of carbon C atom, three p obitals and a single 2s orbital hybridized (blend) to make four sp^3 hybrid orbitals “Fig. 3”.

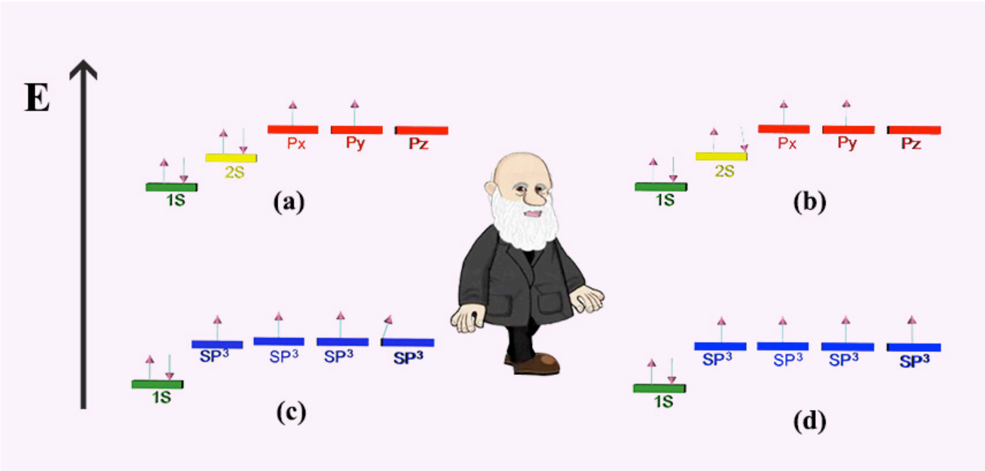

Figure 3: Animation guided by Darwin, pointing out how in the case of carbon C , starting from the ground state of atom C (a), passes to the excited state (b) and then to hybridised states (c - d), where the sp^3 hybrid orbitals are formed

2.3 Educational activities

Educational activities are useful in evaluating students' prior science/chemistry knowledge, determine their misconceptions, and then build their mental models with upgraded scientific cognition. They provide smart didactical approaches that overall help students in their learning process. For example in order the student to get familiar and understand concepts such as the hybridized orbitals (sp, sp2, sp3 with full capabilities of rotation and size changing), we construct a drag and drop activity that direct students in a learning cycle assigning the names of the orbital and its geometric arrangement to the correct 3D graphic "Fig.4".

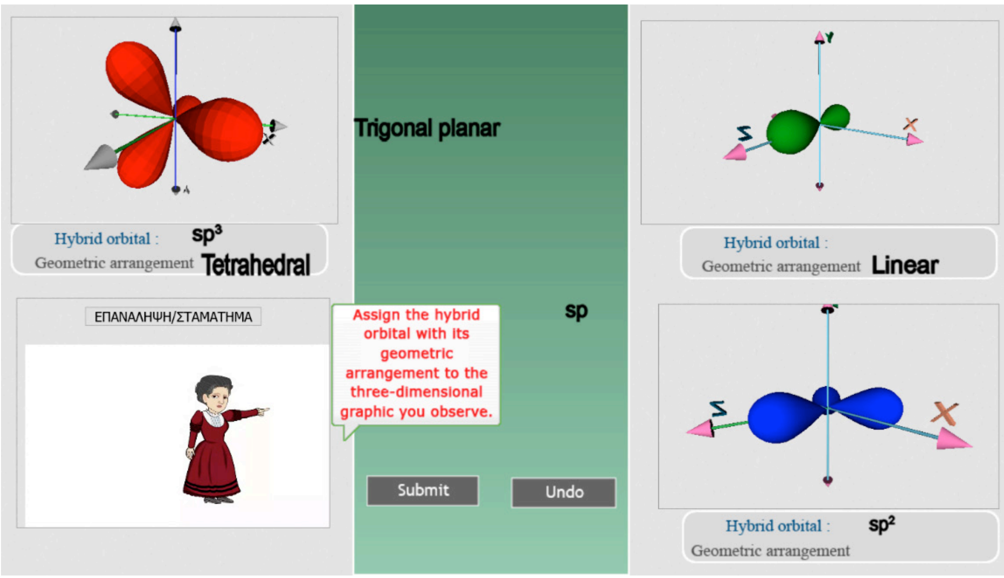

Figure 4: Drag and drop activity guided by an interactive cartoon avatar "Curie", on the thematic section in hybridized orbitals

Moreover because we want to evaluate students' scientific cognition on chemistry concepts, we have designed an activity where we ask them to draw a specific concept i.e. the molecular model of PF3, based on its geometry arrangement "Fig.5". In this particular activity we expect students to act by themselves based on their own knowledge.

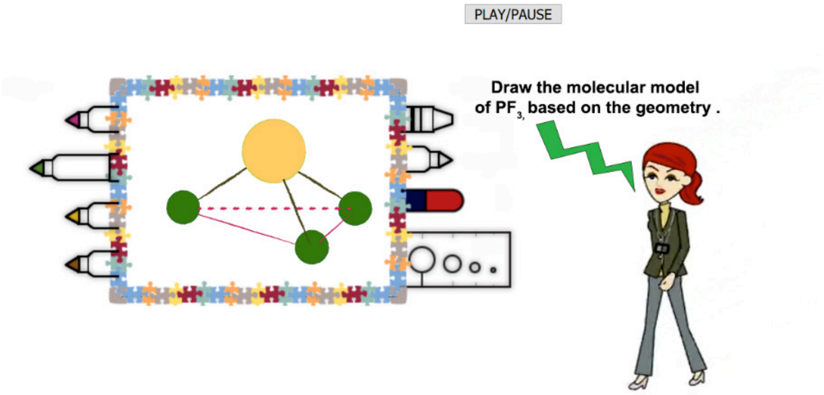

Figure 5: Educational activity with drawing the molecular model of PF_3, taking into consideration its molecular geometry.

2.4 Educational games

Educational games provide pleasant activities that students prefer to participate in. This assumption agrees with the results of the Antunes [13] research, who evaluated the effectiveness of an educational game about molecular geometry, polarity, and intermolecular forces, in reconstructing students' knowledge, in a general chemistry course for engineering students. To this end, we have constructed educational games such as flipping cards that demands the cross-matching of the right concept with the adequate graphic, in the thematic unit of molecular geometry "Fig.6", based on the VSEPR theory. Specifically there are six couples of matching cards. An example is the cross-matching of the card of sulfur dioxide SO_2 with the card presenting the corresponding geometry model of planar trigonal, bent angled.

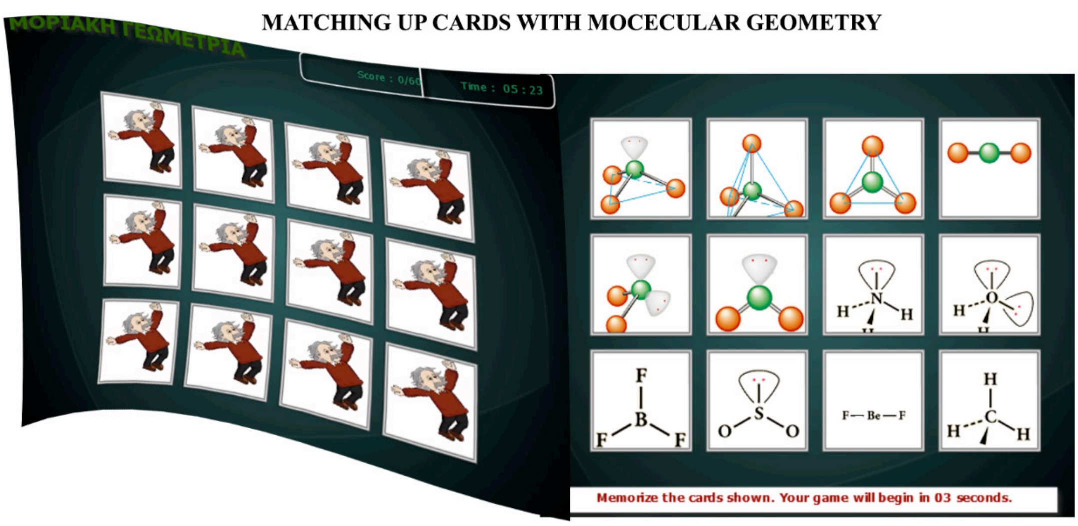

Figure 6: Educational game with flipping cards that demand the cross-matching of the right example with the adequate graphic / molecular geometry

3 DISCUSSION – CONCLUSIONS

The educator or even the teacher indicated that the way he/she interprets any visual representation is mostly influenced by his/her sciences' expertise and knowledge, showing that his/her intuitive judgment has been explicitly shown to be largely untrustworthy, i.e., graphics that look completely fine to the academic teacher can turn out to be confusing to students [14]. To this end we constructed 3D visualizations with capabilities of free rotation and size changing, in order to provide students the opportunity to study by themselves the concept that caused difficulties in their learning process. The main idea was that undergraduate students must have an active involvement and control by themselves the rhythm they preferred to rebuild their scientific knowledge.

Since the majority of chemistry concepts, such as hybridization or orbitals, are not directly perceivable as they link with the microcosm, learning a chemistry concept predominantly involves activating existing perceptual symbols and combining them in novel ways to form new knowledge. This would suggest that the goal of any type of instructional representation used in teaching chemistry, be it visualization, or animation, and should be to correctly activate a set of existing perceptual symbols, so that the brain can combine them into an upgraded mental model. The question then becomes "how exactly can instructional representations activate perceptual symbols?" The most common method, of course, is the teacher to talk about it, or more precisely, to present a visualization that has already been associated with an existing simulation consisting of multiple perceptual symbols. For instance if the teacher want to teach concepts such as hybrid orbitals sp^3 (that are taught in the secondary education and cause misconceptions to the students) and explain their contribution in the forming of covalent bonding crystal "diamond", that overall explains its property of hardness, he/she can use in the classroom a blended teaching method: combining dialogue with students in order to understand what they already know, using 3D visualizations to give students the chance to study the 3D graphic by themselves, rebuild correctly their scientific knowledge and evaluate them with an instructional activity such as a drag and drop. The main purpose of this proposed guided teaching technique is that students must understand that they have to follow suggested educational and instructional strategies in learning and deeply understand high cognitive concepts in higher education.

The authors of this article constructed a digital material based on cartoons, animations and 3D visualizations, with multimedia applications aiming to focus on students' visual attention and avoid the split attention effect. Using Mayer's definition of multimedia as "the presentation of materials using both words and pictures" [15], it can be seen that split-attention will frequently occur using multimedia as there will always be at least two sources of information involved, text and graphic (3D or 2D with animation or static). The split-attention principle states that educators and the academic community when designing instruction, including multimedia instruction, it is important to avoid formats that require students to split their attention between, and mentally integrate, multiple sources of any kind information. By eliminating the need to mentally integrate simultaneously multiple sources of information, extraneous working memory load is reduced, freeing resources for learning [16].

The authors believe that new multi-dimensional use of educational practices and techniques based on well-known and accepted pedagogical methods and theories, would work well as a hook to engage students in the powerful connection between macroscopic evidence and the molecular level. When used in this manner, it might motivate students to be more attentive during the lesson. To this end, the main care of the educational community in higher education is to direct students on a learning cycle which will make students' ideas about chemistry explicit and they make chemistry and science interactive and discussion-based. Towards that direction research must be planned, as students do not adequately improve their basic visualization skills in chemistry without being explicitly taught them through specially designed learning activities.

ACKNOWLEDGEMENTS

This research is implemented through IKY scholarships programme and co-financed by the European Union (European Social Fund - ESF) and Greek national funds through the action entitled "Reinforcement of Postdoctoral Researchers", in the framework of the Operational Programme "Human Resources Development Program, Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) 2014 – 2020.

REFERENCES

[1] W.J. González-Espada, "Integrating physical science and the graphic arts with scientifically accurate comic strips: rationale, description, and implementation", *Rev Electrón Enseñanza Las Ciencias*, vol. 2, pp.58–66, 2003

[2] C. Gomez, "Teaching physical geography at university with cartoons and comic strips: motivation, construction and usage", *N Z Geog*., vol. 70, pp.140–145, 2014.

[3] K. Dalacosta, M. Paparrigopoulou-Kamariotaki and E. Pavlatou, "Can We Assess Pupil's Science Knowledge with Animated Cartoons?" *Procedia Social and Behavioral Sciences*, vol. 15, pp. 3272-3276, 2011.

[4] B. Keogh and S. Naylor, “Concept cartoons, teaching and learning in science: an evaluation”, *International Journal of Science Education*, vol. 21, no 4, pp.431–446, 1999.

[5] E.Ö. Köse, “Effects of cartoons on students’ achievement and attitudes in biology teaching (endocrine system)”, Kastamonu Education Journal, vol. 21, no 3, pp. 931-944, 2013.

[6] M. Kumasaki, T. Shoji, T. Tsung-Chih Wu, K., Soontarapa, M. Arai, T. Mizutani, K. Okada, Y. Shimizu and Y. Sugano, “Presenting Safety Topics Using a Graphic Novel, Manga, To Effectively Teach Chemical Safety to Students in Japan, Taiwan, and Thailand”, *J. Chem. Educ.*, vol. 95, no 4, pp. 584–592, 2018.

[7] B. Çelik, K. K. Gündoğdu, “The effect of using humor and concept cartoons in high school ICT lesson on students’ achievement, retention, attitude and anxiety”, *Computers & Education,* vol. 103, pp.144-157, 2016.

[8] R. Kelly, “Using Variation Theory with Metacognitive Monitoring To Develop Insights into How Students Learn from Molecular Visualizations”, J. Chem. Educ., vol. 91, no 8, pp 1152–1161, 2014

[9] G. Marbach-Ad, Y. Rotbain, and R. Stavy, “Using computer animation and illustration activities to improve high school students’ achievement in molecular genetics”, Journal of Research in Science Teaching, vol. 45, pp. 273–292, 2008.

[10] R.E. Mayer and R. Moreno, “Aids to computer-based multimedia learning”, *Learning and Instruction*, vol. 12, pp. 107–119, 2002.

[11] P. Maier and G. Klinker, “Augmented chemical reactions: 3D interaction methods for chemistry”, *International Journal of Online Engineering (iJOE)*, vol. 9, pp.80–82, 2013.

[12] T. Barrett, T. A. Stull, M. T. Hsu and M. Hegarty, “Constrained interactivity for relating multiple representations in science: When virtual is better than real”, *Computers & Education*, vol. 81, pp.69-81, 2015.

[13] M. Antunes, MAR. Pacheco and M. Giovanela, “Design and implementation of an educational game for teaching chemistry in higher education”, *Journal of Chemical Education*, vol. 89, no 4, pp.517-521, 2012.

[14] C. E. Wieman and K. K. Perkins, “A powerful tool for teaching science”, *Nat. Phys*., vol 2, pp.290-292, 2006.

[15] R. E. Mayer, *Multimedia learning*. New York: Cambridge University Press, 2001.

[16] P. Ayres and J. Sweller, “The Split-Attention Principle in Multimedia Learning”, In R. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (Cambridge Handbooks in Psychology), pp. 206-226, Cambridge: Cambridge University Press, 2014.