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Chemistry teacher candidates' acceptance and opinions about virtual reality technology for molecular geometry

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The meaningful knowledge creation about molecular geometry has always been the challenge of chemistry learning. In particular, microscopic world of chemistry science (example, atoms, molecules, structures) used in traditional two dimensional way of chemistry teaching can lead to such problem as students create misconceptions. In recent years, virtual reality (VR) technology has been widely proposed as an innovative technology that can provide highly realistic, immersive and interactive three dimensional environments for learning experiences. In this study, a desktop virtual reality technology for molecular geometry learning was created to be employed in chemistry education. The purpose of the study was to examine the acceptance and intentional use of VR technology by chemistry teacher candidates, and their opinions of psychological effects of VR on teaching and learning chemistry concepts. The results showed that perceived usefulness and perceived ease of use are positively related to the behavioural intention to use VR tool. Moreover, the findings revealed that chemistry teacher candidates showed positive beliefs about the features of VR technology in terms of facilitating understanding, allowing to learn fast, enhancing the motivation, and easing thinking schematically.

Key words: Chemistry teaching, virtual reality technology, molecular geometry, technology acceptance.

INTRODUCTION

Learning and teaching chemical concepts (example, atoms, molecules, structures, substances) constitutes a challenging task (Gilbert et al., 2004; Talanquer, 2012) due to the fact that learners are required to establish a relationship between micro- and macro-worlds of chemistry (Johnstone, 1993). In particular, learners often have difficulties in understanding chemical concepts, structures, and processes at the particulate level, and making connections with the macro level (Nakhleh, 1992). Molecular geometry is one of the fundamental chemistry concepts about which learners usually create mental models and/or representations that contradict the scientific knowledge; as a result many misconceptions have been reported in terms of learners' experiences about the notions of chemistry (Garratt et al., 2000; Gillespie et al., 1996; Huddle et al., 2000; Nakhleh, 1992).

Choosing the central atom, completing its valence shell, and drawing the Lewis structure are among the

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learning difficulties that learners posses (Al-Mousawi, 1990; Wan-Yaacob and Siraj, 1992). Moreover, it has been recognized that learners have the knowledge of valence shell electron pair repulsion (VSEPR) theory but they usually experience difficulties in using and applying this knowledge (Birk and Kurtz, 1999; Furió et al., 2000; Peterson et al., 1989). Teaching molecular geometry using VSEPR model could be a challenging task for instructors (Lindmark, 2010).

In a traditional classroom setting, molecular geometry is typically taught by lecturing, and using the chalk and the blackboard. The instructors generally introduce the topic with some examples about the basic shapes of the molecules, and foster students to apply the rules of the VSEPR theory by using plastic ball and stick models. However, the ball and stick models are rigid, and students commonly have difficulties in comprehending the differences in bond angles of different structures. Another difficulty with the ball and stick models is that they consist of the same size of atoms though they are in different colours. Thus, the ball and stick model does not adequately represent the 3-dimensional arrangement of the molecule structure.

Therefore, it is crucial to utilize the most appropriate learning and teaching tools that help learners improve their conceptual understanding in an effective way. It is strongly claimed by researchers that new instructional materials supporting 3-dimensional visual tools and models are ought to be employed in order to improve learners' understanding of chemical concepts (Fruio and Calatayud, 1996; Levy, 2013; Williamson, 2008), and constructing and evaluating scientific knowledge (Schwarz et al., 2009).

Henceforth, alternative and innovative educational methodologies based on new technologies are required to address the above-mentioned problems. As in many other sectors, the use of new and emerging technology has gained a tremendous interest as a catalyst to bring significant transformation in education sector. Innovative technology-based applications are increasingly gaining ground over traditional learning and teaching methods by facilitating the lone and/or collaborative activities of learners. The transition from the traditional learning and teaching approach to technology-based learning experiences and solutions provides significant benefits for learners with a variety of learning resources and tools. Virtual Reality (VR) technology has emerged in the education sector and been demonstrated as an effective tool for better learning and teaching experiences. Recently many instruction and research efforts have been conducted aiming to take advantage of its potentials. In the case of chemistry, VR provides "highly realistic and believable simulations of chemical procedures within a fully-immersive, interactive and three-dimensional virtual world" (Georgiou et al., 2007).

The VR technology is expected to exploit the benefits to facilitate and enrich learning and teaching chemistry concepts by helping learners clarify their unclear conceptions. In this study, a learning tool, namely a desktop VR molecular geometry (VRMG), was designed and developed, and practiced by teacher candidates for molecular geometry learning experience. This research aims to examine the acceptance and intentional use of VR technology by chemistry teacher candidates, and their opinions of psychological effects of VR on teaching and learning chemistry concepts.

Desktop VR

"Chemistry is a conceptual subject and, in order to explain many of these concepts, models are used to describe and explain the microscopic world and relate it to the macroscopic properties of matter. As students progress in chemistry the models they use change, and many contradict their everyday experiences and use of language" (Taber, 2002). In particular, representational languages, forms and/or notations of microscopic world of chemistry science (example, atoms, molecules, ions, structures) used in traditional two dimensional way of chemistry teaching can lead to such problems as students create misconceptions, and thus influence the learning outcomes.

Lately, the utilization of innovative and emerging technologies in education has provided opportunities for designing new learning environments that support realistic, authentic, meaningful, and engaging learning experiences (Dede, 2010b). In fact, these learning contexts strongly support the notion of active learning instead of passive acquisition of others' knowledge (Dede and Barab, 2009). Researchers advocate that emerging technologies enhance learners' engagement in learning (Barab et al., 2007; Chase et al., 2009; Squire and Jan, 2007).

VR technology has widely been recognized as a significant technological advance that can provide opportunities and learning experiences for students who can interact with microscopic molecular structures in a highly realistic 3D simulation supporting immersive features (Georgiou et al., 2007). What truly is virtual reality? it is a real-time high-speed three dimensional graphical simulation or a highly interactive, "realistic" computer-based multimedia environment that can detect user's actions and change in accordance, and allows users to become a participant in that environment with various stimuli including sound and tactile sense, user control of the viewpoint's motion, and a rich set of accessible options (Ferrington and Loge, 1992; Moshell and Hughes, 2002; Shin, 2002; Chen et al., 2007; Limniou et al., 2008; Sun and Cheng, 2009). The user's actions are sensed in such virtual environment in which participants can have the feeling of being mentally immersed (Muhanna, 2015).

"VR refers to a new computational paradigm that fundamentally redefines the interface between humans and computers" (Bricken, 1990). As Bricken (1990) claims that learning via VR is certainly not an abstract list of words, graphs or formulas within a textbook, it is rather what an individual does and perceives in his/her environment allowing to do experiments, observe the consequences and then construct the knowledge (Bricken, 1990). Using this technology, instructors can create virtual learning environments in which students can interact with virtual real-like objects related to a scientific concept, which especially cannot be studied and/or observed at macro or tangible level. "Besides, the most critical feature of VR - that is, to present a real and interactive learning environment which is seen as a lack of many other educational technologies, it supports first-person experiential learning. VR can promote learners' metacognitive skills such as reflecting, thinking, questioning, analysing, evaluating and decision-making" (Sarıtaş, 2010). VR technology offers educators the unique affordances in enhancing cognitive skills. For instance, educators have the opportunity to create replicas of real life places (example, second life) where users actively engage in realistic learning activities, to teach scientific inquiry and abstract concepts (Merchant, et al., 2014).

Although VR technology in various studies has been documented that it enhances learning effectiveness, it has limitations especially in terms of its integration into classroom teaching due to its inaccessible to teachers and learners because of complex equipment and high cost (Ausburn and Ausburn, 2004). However, with recent improvements in virtual reality modelling languages (VRML) and flashbuilder programming languages, desktop VR technology has shown its presence and presented its low-cost applications that can be created and adopted easily by teachers and presented to students through a webcam on desktop screens. Therefore, desktop VR can be a valuable and suitable educational tool for teachers to integrate this powerful and high-impact technology into either traditional or virtual classrooms (Sarıtaş, 2010).

METHODOLOGY

Research subjects

This study involved 29 undergraduate students (who are also chemistry teacher candidates for secondary or high schools) from the department of chemistry education in the Faculty of Education, at a public university in Aegean region of Turkey. There were 16 male and 13 female participants with an average age of 20. The participants are university students who are all acknowledgeable about the basic use of computer technology. They also took the course called "Introduction to Chemistry Teaching." Before the study, it was confirmed by all participants that they had enrolled in general chemistry course offering the subject-matter knowledge of molecular geometry. This was important for the study since no instruction related to the relevant subject matter took place but the pre-knowledge of it was necessary to examine the instructional tool created by VR technology.

Research preparation and context

This study mainly focuses on the design, utilization and effectiveness of an innovative technology, namely VR technology, being as a learning and teaching tool on the comprehension of micro-worlds in molecular geometry. The two chemistry professors who lecture the "General Chemistry" class at the faculty of education were interviewed with before designing and developing the desktop VR learning tool to enhance the understanding of learners about molecular geometry. The professors agreed to participate in this study as consultants for a learning activity. The professors were consulted several times in the design process of VR tool at different stages.

VR tool was designed and developed (Figure 1) to foster cognitive skills in constructing meaningful learning (Bodner, 1986). The VR tool was designed in way that learners could find an opportunity to restructure or revise their models within molecular geometry, as they were able to interact with the VR tool. The VR tool compatible with different operating systems allowed users to interact with and investigate atom molecules in 3 dimensional models by different angles and sizes (example, zooming and rotation tool) based on their individual preferences. It has been reported that learners create accurate understanding of concepts as they interact individually with the learning tool and environment (Schwarz et al., 2009).

VR tool consists of software and a marker (example, the interaction tool with the software). Instead of producing many markers for each molecule, only one marker for all molecules was designed and developed. With this marker within the camera's view, the user can easily observe the different types of molecules by selecting the molecule number on the menu within the interface of the software (Figures 2, 3 and 4).

Prior to the use of VR tool, the teacher candidates were given a 3 h seminar about the idea of VR technology, and were provided with examples of VR tool similar to the proposed one in this study (example, markers and interface) from different fields such as biology and physics. The purpose of this activity was to get pre-service teachers familiar with VR environment, which they encountered with the very first time. Later, they employed, tested and interacted with the VR tool through self- and collaborative-exploration at a computer laboratory setting (Figure 5).

Research questions

The following research questions were investigated in the study:

1. What is the intention of teacher candidates toward the use of VR technology as a learning tool in chemistry teaching?
This research aims to explain teacher candidates' Virtual Reality Technology acceptance from a measure of their actual system use, their intention to use, perceived usefulness, perceived ease of use, and a related variable – interface style.
2. What are the opinions of teacher candidates about the

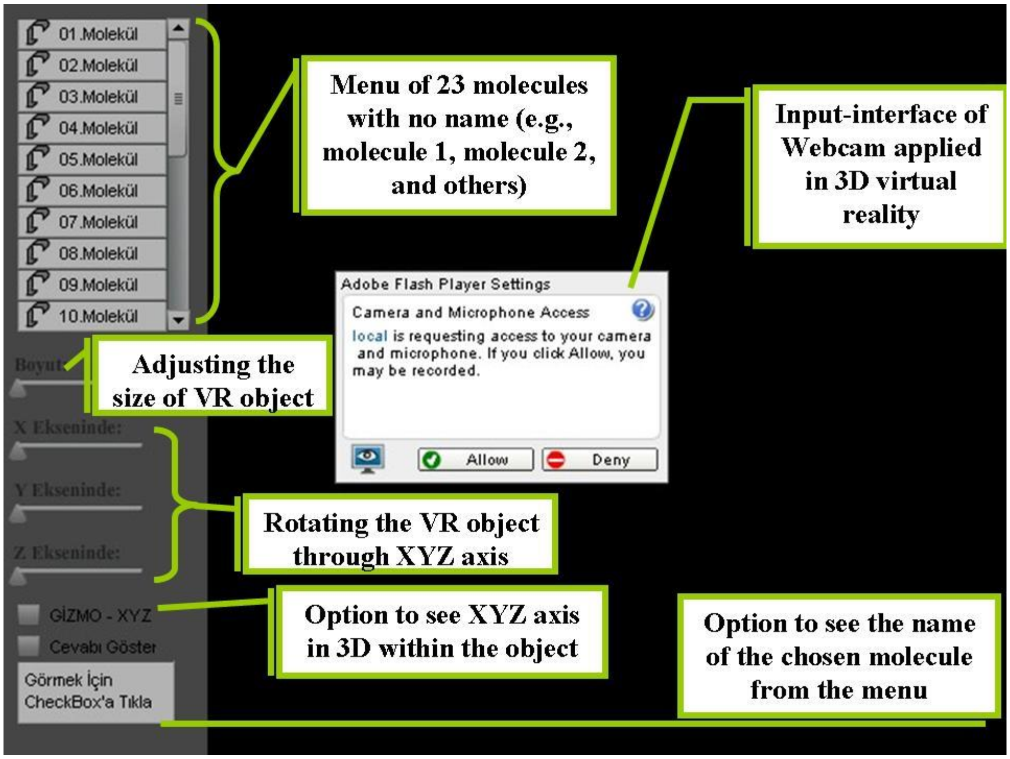

Figure 1. Input interface of desktop virtual reality for molecular geometry teaching.

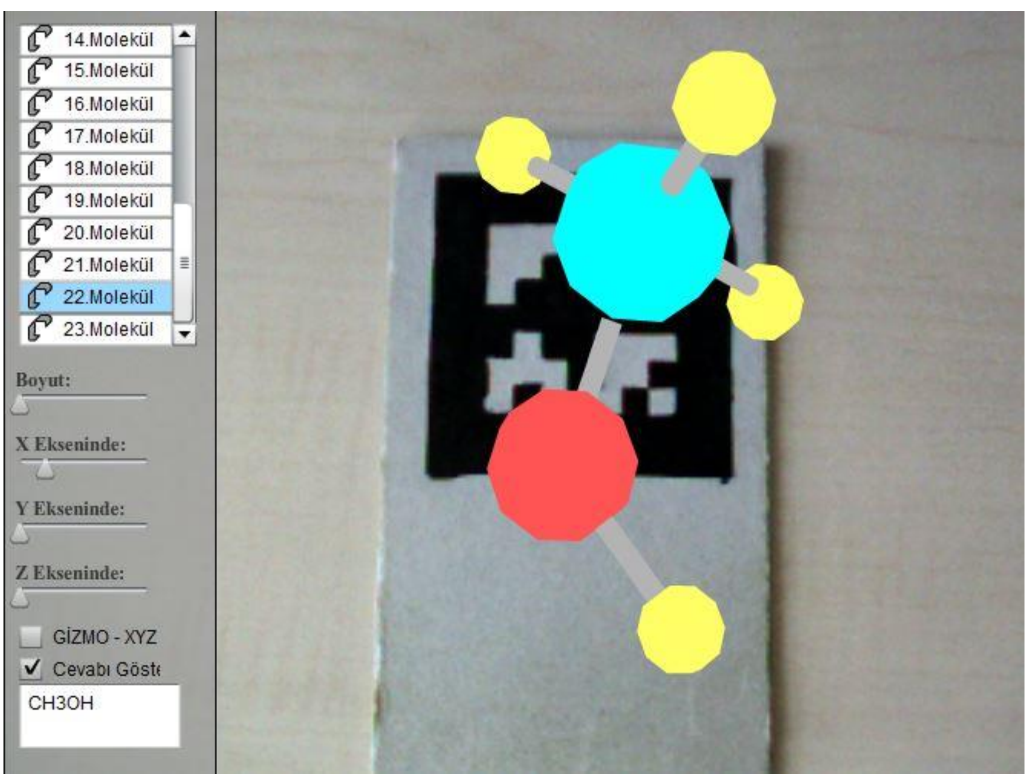

Figure 2. VR model of the molecule - CH_3OH.

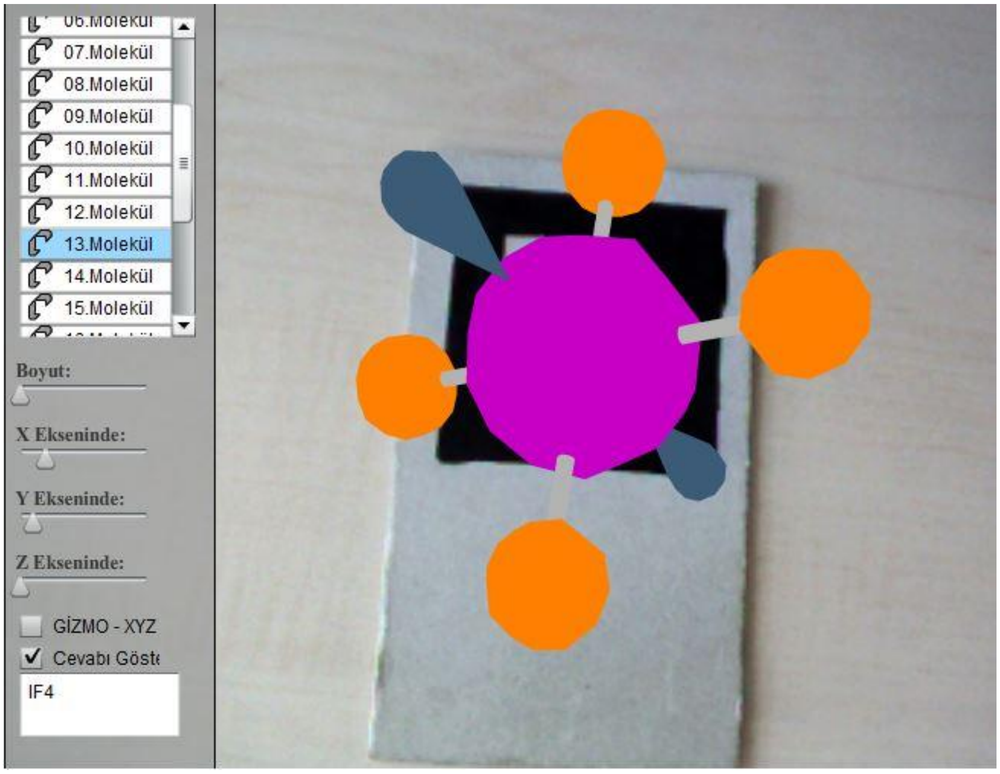

Figure 3. VR model of the molecule - IF_4.

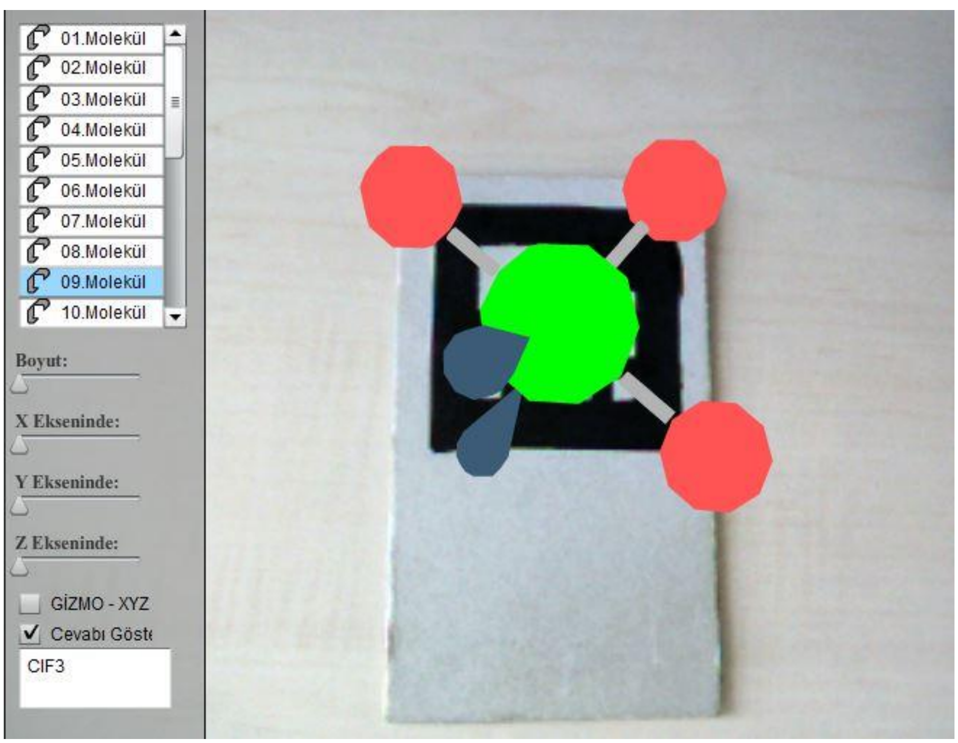

Figure 4. VR model of the molecule - ClF_3.

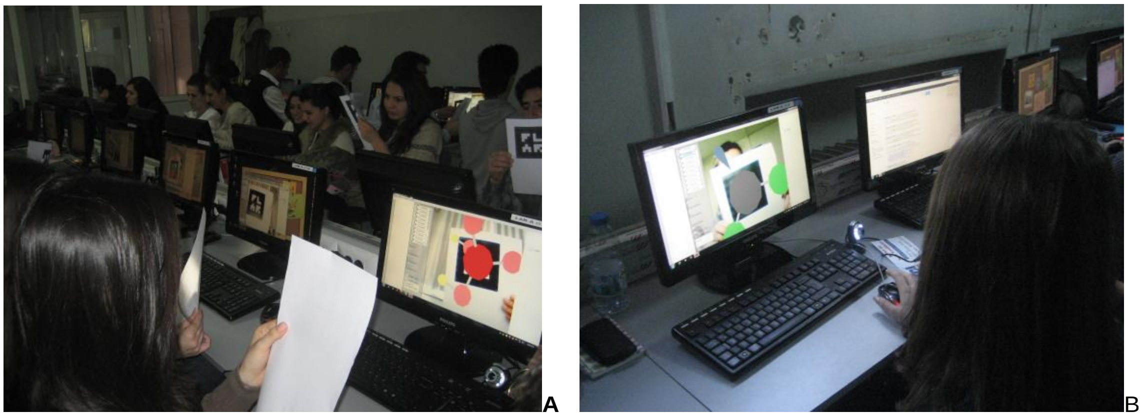

Figure 5. (A-B). Photographs of students interacting with computerized molecular models created by desktop VR using webcams and marker cards.

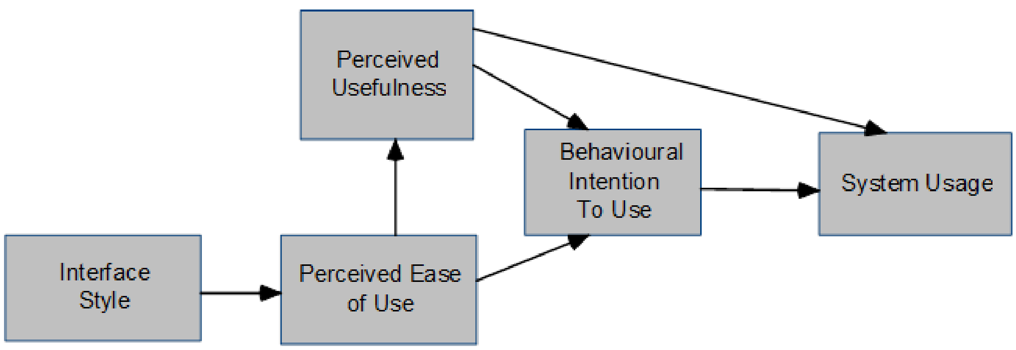

Figure 6. Technology acceptance model (adopted from Venkatesh and Davis, 1996).

psychological effects of desktop VR technology on learning and teaching molecular geometry?

3. What do teacher candidates think about the potential uses of VR in chemistry education?

Data collection Instruments

Technology acceptance model

Technology acceptance model (TAM), proposed by Davis in 1986, is one of the widely recognized and used models to predict and explain user behaviour and acceptance of an information system. The purpose of TAM is to explain the reason(s) why user accepts or rejects to use an information technology and how external variables influence the user's intention to use it. In this study, TAM proposed by Venkatesh and Davis (1996) (Figure 6) was used to predict whether teacher candidates were willing to accept VR technology in molecular geometry teaching (Appendix 1).

As suggested in TAM, one's acceptance of a technology system is represented by actual use of that system which is determined by the user's behavioural intention to use the system. Intention to use a system is influenced directly or indirectly by the user's perceptions of usefulness, and ease of the system. Perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance… the definition of the word useful: capable of being used advantageously" (Davis, 1989). Perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989).

According to TAM, perceived usefulness is determined by perceived ease of use. TAM also proposes that perceived usefulness and perceived ease of use can be affected by various external factors that may have an influence on intention and actual use of the system. In this study, interface style was considered to be an external variable that may have an effect on perceived ease of use. Since the interface of the VR technology is differentiated from other learning environments, interface style was explored as an external variable that may have an influence on the main constructs directly determining the system usage. The following research hypotheses were investigated on the basis of the TAM model above:

H1. Perceived usefulness is positively related to behavioural intention to use.

H2. Perceived usefulness is positively related to system usage.

Table 1. Regression weights.

Variable			Estimate	S.E.	C.R.	P
Perceived ease of use	<---	Interface style	0.611	0.154	3,975	***
Perceived usefulness	<---	Perceived ease of use	0.312	0.171	1,820	.069
Behavioural intention to use	<---	Perceived ease of use	0.337	0.138	2,431	.015
Behavioural intention to use	<---	Perceived usefulness	0.393	0.144	2,723	.006
System usage	<---	Behavioural intention to use	0.099	0.217	.457	.647
System usage	<---	Perceived usefulness	0.807	0.205	3,941	***

H3. Perceived ease of use is positively related to perceived usefulness.
H4. Perceived ease of use is positively related to behavioural intention to use.
H5. Behavioural intention to use is positively related to system usage.
H6. Interface style is positively related to perceived ease of use.

Questionnaire

A number of research studies in the literature of metacognitive knowledge suggest that users develop personal beliefs and opinions about the implications and features of educational technologies that they are asked to employ in instructional settings (Antonietti and Giorgetti, 2006; Baylor, 2001; Smith et al., 2000). Metacognitive knowledge consists of sets of beliefs (example, personal attributes, task features and strategies), which are relevant to learning mediated by educational technologies (Antonietti et al., 2008; Veenman et al., 2002). Among the various psychological aspects within the notion of metacognition, Antonietti et al. (2008) put an emphasis on the user belief only in their study, namely, the psychological effects of technologies employed for educational aims. There is a need in the literature to investigate the metacognitive beliefs that are developed during the learning process supported by technology (Antonietti et al., 2008).

The questionnaire developed by Antonietti et al. (2008) was administered to obtain opinions of teacher candidates about the psychological effects of desktop virtual reality technology in the case of molecular geometry teaching and learning (Appendix II). The questionnaire included items about "the motivational and emotional aspects of learning, the behaviour to have during the learning process, the mental abilities, the style of thinking required, and the cognitive benefits" (Antonietti et al., 2008). A reliability analysis suggests that the questionnaire is reliable (the Cronbach's Alpha coefficient is 0.83).

The questionnaire consists of seven constructs: facilitation, motivation/impact, rapidity/intuition, creativity, logical-analytical thinking, global view and negative effects. The questionnaire is designed using Likert scale with five options: a scale of 1, or ''strongly disagree'', to 5, or ''strongly agree''. All responses received from 29 participants were valid.

Interview protocol

Interview was conducted to explore further the opinions of teacher candidates about the utilization of VR technology in chemistry education. The following questions were asked during the interview.

1. What are your impressions and general thoughts about the use of VR tool in chemistry education?
2. How will VR help you and your students in the learning process?
3. If you want to improve the VR learning tool, what would it be?
4. Would you recommend VR as an instructional tool to your colleagues?

Data analysis and findings

VR technology acceptance of participants

A structural equation modelling (SEM) was conducted to test the technology acceptance model shown, that is, examine the positive and negative relationships between the constructs, and their statistical significance (Table 1). The overall goodness-of-fit measures representing the entire set of causal relationships were calculated. The overall goodness-of-fit measures indicated a good fit for the model (Chi-square X^2 /DF: 2.1; GFI: 0.985; RMR: 0.01, RMSEA: 0.001). Table 1 shows that interface style had significant effect on perceived ease of use (R^2 0:61, p = 0.000). The regression weight for perceived ease of use in the prediction of behavioural intention to use is significant at the 0.05 level (two-tailed) (R^2 0:33, p = 0.015). However, the direct effect of perceived ease of use on perceived usefulness was not significant (R^2 0:31, p = 0.069). Perceived usefulness had a significant effect on behavioural intention to use (R^2 0:39, p = 0.006) and system usage-actual system use (R^2 0:80, p = 0.000). The direct effect of behavioural intention to use on system usage was insignificant (R^2 0:10, p = 0.647). The relationships between constructs showed that H1, H2, H4, H6 hypotheses were supported, whereas H3 and H5 hypotheses were not supported.

Psychological effects of VR technology

The mean value of each construct was calculated in the questionnaire analysis. It can be seen in Figure 7 that "Facilitation" has the highest mean value, which suggests that teacher candidates revealed a positive opinion of VR technology in terms of facilitating the learning process, making conceptual knowledge convincing. In addition, the construct "creativity" has the second highest mean value, which indicates that the use of VR technology stimulate users to be creative. Logical-analytical thinking is another construct that follows the first two with a mean value of

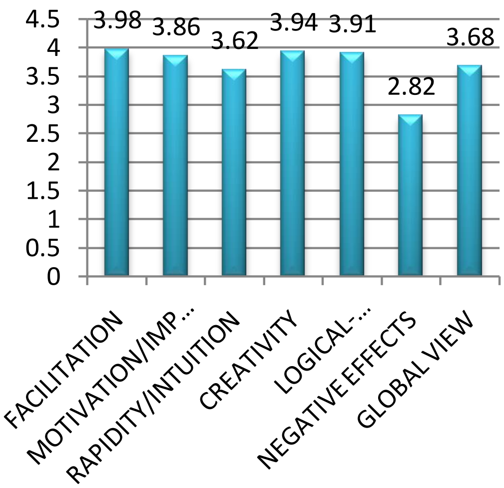

Figure 7. Psychological effects of VR.

3.91. This finding suggests that VR technology is an effective tool in order for learners to schematise scientific concepts. Negative effects were found to be the construct that has the lowest mean value. The picture about that is, actually, encouraging since it includes negative items describing limits and risks of using VR in educational contexts.

Teacher candidates rated the psychological features of VR tool based on their experiences of using it in the subject-matter knowledge of molecular geometry. Table 2 shows the statements that obtained the highest and the lowest mean scores. According to teacher candidates, VR tools "are useful to schematise concepts", which has the highest rate (Mean=4.39). They also appreciated very much the opportunity that VR tool allow to make comprehension easier (Mean=4.32). Furthermore, teacher candidates developed beliefs about the beneficial use of VR technology in facilitating understanding through imagination (Mean=4.18), encouraging to be creative (Mean=4.07), allowing to learn fast (Mean=4.04), enhancing the motivation to learn (Mean=4.04), making notion application easier (Mean=4.00) and convincing (Mean=3.96), facilitating thinking schematically (Mean=3.96), allowing to monitor learning progress (Mean=3.96), and making links and comparisons between concepts (Mean=3.96).

According to teacher candidates, however, the application of VR in chemistry education requires learners to have an imagination (Mean=3.57), plan actions (Mean=3.57), and think simultaneously about various things (Mean=3.43). This result suggests that the employment of VR-based instructional tool is not as satisfactory as that of other constructs earlier mentioned which needs to be further improved. While using the VR learning tool, quick reflexes, which a user should have for the ease of learning, was found to be another construct that obtained a lower mean (Mean=3.25). Although these statements were rated with lower mean values, they could also be considered as consequential due to the fact that they are above the average score of 3. The features of VR tool in chemistry education including those that "may be confusing" (Mean=2.36) and "are tiring" (Mean=2.31) obtained the lowest mean values. Nonetheless, they indicate negative psychological effects of VR tool in molecular geometry learning, which could be considered as an assuring result.

Teacher candidates' opinions about VR

Interview questions were conducted with 5 volunteered teacher candidates to obtain their opinions about the VR learning tool that they used for molecular geometry education. Some of the responds to the 4 interview questions were as follows:

1. What are your impressions and general thoughts about the use of VR tool in chemistry education?

"It was the first time I have encountered with this kind of technology. It was very interesting, and so that entertaining and understandable."
"It was very impressive. It makes you focus on the right point, which is so inspiring."
"I was very surprised! The best thing I liked with it is a perfect tool to amplify and realize the imagination."
"It is so exciting that triggers the learning and motivation to learning."
"It was good to see the visual representations of molecules in 3D."

2. How will VR help you and your students in the learning process?

"*I had a feeling that the classes will be easier with VR. The learning will be faster and the motivation will increase dramatically. It will facilitate both understanding and teaching in a way that students will be exposed to a more captivating and enjoyable learning process."*
"I think this application will very beneficial for all teachers, particularly, in lecturing abstract concepts in chemistry. Students will become more active learners and eager to learn more."
"I think this is going to be an effective instructional tool because it will allow easy understanding by visualizing the theoretical knowledge. It will also take attentions of students during lectures. The more visualization the learning tool offers, the more retention of knowledge is."
"I would like to make plans and design a teaching activity

Table 2. Statements about VR that obtained the highest and lowest mean values.

Desktop VR technology for molecular geometry learning:			
Statements which obtained the highest mean values			
Mean value		**Mean value**	
Are useful to schematise concepts	4.39	Make notion application easier	4.00
Make comprehension easier	4.32	Allow people to check immediately what have learned	3.96
Facilitate people who have much imagination	4.18	Make notions convincing	3.96
Stimulate people to be creative	4.07	Facilitate persons who tend to think schematically	3.96
Allow people to learn fast	4.04	Induce and/or facilitate people to make comparisons and links	3.96
Support or enhance motivation	4.04	-	-
Statements which obtained the lowest mean values			
Mean value		**Mean value**	
Require imagination	3.57	Facilitate persons who have quick reflexes	3.25
Require to plan actions	3.57	May be confusing	2.36
Require to think simultaneously about various things	3.43	Are tiring	2.31

about my profession with the help of this VR tool."

3. If you want to improve the VR learning tool, what would it be?

"It was hard to hold the marker for a long time in front of the webcam. There should be another way."
"The quality of visual representations needs improvement."
"The most I liked about it there was a change in the size and movements with an external input. It would be better if there were a sense of touching."
"I wish to have a full control of the objects in the screen with my hands."
"I wish to make changes and improvements about molecules, that is, the opportunity to be able to do design within the software."

4. Would you use VR as an instructional tool and recommend to your colleagues in future?

"I will definitely search for the potential uses of VR in my classes."
"I will absolutely use VR and recommend it to other teachers because it promotes creativity – helps learners create mental models about molecules."
"I will recommend it since it supports new learning attitudes of 21st century students through development of imagination with the help of 3 dimensional features."
"I believe that this tool is an effective one but every student has a different learning style. Thus, some learns visually, some learns verbally in a better way."
"I would recommend it might be for further future because there are no enough infrastructures in our classes today."

Based on the interview results, all respondents showed a very good impression about VR and expressed a willingness to use it as an educational tool in teaching chemical concepts in the future. Enhancing motivation, facilitating the understanding of sub-micro concepts, and creating meaningful learning were the mostly mentioned advantages of VR tool among others. While, some mentioned that markers and visual objects would have been better in quality. One teacher candidate suggested the virtual objects, as they can be editable and improvable according to the preference of the user.

DISCUSSION

In this study, a desktop VR technology supporting immersive 3D features was designed and proposed as a tool that can influence learning outcomes by helping learners engage in learning activities at their own comfort and pace. This research tried to make a contribution to the literature by providing an empirical study about the implementation of VR and understanding the potential of it to support and enhance learning in chemistry education. Based on the research questions, the following conclusions were made.

First, following the empirical study, it was found that users' perceptions about the usefulness of VR were a much more significant factor in determining the intention to use it in real life learning contexts than their perceptions about its ease of use. This result indicates that teacher candidates have acknowledged the potential educational benefits that VR may bring into chemistry teaching more importantly than its technical ease of use. Yet, interface style, which represents the interaction between the user and the system, was found to be a significant variable that is positively associated with the perceived ease of use. Interface style plays an important role in reducing the cognitive effort needed to develop complex mental models about molecule geometry. Although perceived usefulness is positively related to the system usage, however, teacher candidates' behavioural intention to use VR was not significantly related to the actual system use. This result suggests that the intention to use it does not necessarily mean that teacher candidates will actually use the system.

Second, VR learning tool combining interactive 3D content with real physical environment provides learners with opportunity to interact with the content in an intuitive way, thus perform a personalized learning experience. This active participation results in developing different beliefs, or psychological effects, about the use of VR. The results showed that, according to teacher candidates, VR could be used as a means of facilitating, motivating, and encouraging the learners' understanding of chemical concepts. The application of VR technology was found to be very useful especially to schematise concepts, which is a need for chemistry learning at particulate level. It was noted that VR technology provides a rich solution and makes it easier for understanding chemical conceptual knowledge. In addition, making comparisons and links between chemical concepts was highly facilitated by VR learning tool. Though, it requires thinking simultaneously about various topics in chemistry.

Third, in general, chemistry teacher candidates provided positive evaluations about the use of VR tool in chemistry education, as it was suggested by the interviews. They all stated that they would use VR as an alternative and additional resource to reinforce the comprehension of conceptual knowledge, and to help counter misconceptions. Because VR provides a good representational language or form of molecules, teacher candidates evaluated it as an effective tool that increases the motivation, facilitates the understanding, and visualizes theoretical knowledge in a more captivating and enjoyable learning process. However, it was found that the quality of 3D virtual objects needed improvement in quality. Additionally, it was suggested to improve the VR learning tool in that it will allow the user to take control of designing and changing the virtual content.

Based on the findings, it is obviously seen that VR technology, which is implemented with an appropriate set of learning activities, could be a remedial solution for the challenging issues in molecular geometry learning and teaching. VR's spatial ability and features supporting different individual learning styles could diminish misconceptions developed by an individual learner.

The findings of the present study could have some implications to instructional designers, educators and software developers. For instructional designers and educators, VR molecular geometry learning tool has opened new gates for learners and teachers to enhance the learning environment in such ways as realistic, interactive, immersive, and edutainment for digital age learners that have not been previously possible. For software developers, it is now possible to create VR applications with less effort and at low cost. However, they should have in mind a possible set of beneficial psychological effects as well as potential users' needs and expectations deriving from the idea of human-computer interaction.

CONCLUSION

Teaching molecular geometry, one of the fundamental topics in chemistry education, has been a challenge for teachers due to the fact that learners easily develop misconceptions about that. One difficulty with molecular geometry learning is that learners try to determine the shape of a molecule without taking its 3 dimensional shape into consideration (Furió et al., 2000). To remedy this difficulty, researchers have strongly suggested the use of 3 dimensional models for molecular geometry learning (Furió and Calatayud, 1996).

This research study indicated that a new learning tool "desktop VR technology" could be used to minimize learning difficulties and enrich learning experiences within molecular geometry. Efforts should be made to train the teacher candidates to use VR technology effectively in terms of providing feedback, enhancing student collaboration, and making decisions in the design and development of an instructional material (Merchant, et. al., 2014).

Further study should focus on learners' academic achievements and misconceptions as a result of the implementation of VR in chemistry learning contexts. Next, through a comparative research study, achievement scores and the level of misconceptions of learners could be compared between the learners taught with the use of VR and control group taught with traditional methods in molecular geometry learning.

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Conflict of interests

The author has not declared any conflicts of interest.

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Appendix I

Perceived usefulness
1. Using VR would enable to accomplish learning molecular geometry concepts more quickly.
2. Using VR would improve learning performance.
3. Using VR would make learners more productive in the learning process.
4. Using VR would enhance effectiveness in learning molecular geometry.
5. Using VR would make understanding for molecular geometry easier.
6. I believe that VR is useful as a learning tool.

Perceived ease of use
7. Learning to operate VR would be easy for me.
8. It is easy to get VR to do what I want it to do.
9. My interaction with VR is clear and understandable.
10. I would find VR to be flexible to interact with.
11. It would be easy for me to become skillful at using VR.
12. I think VR is easy to use.

Interface style
13. Using the markers for molecular geometry within this input-interface is easy.
14. I could easily interact with this input-interface.
15. Manipulating virtual objects for the chemical experiment is easy.

Behavioural intention to use
16. I intend to use VR for molecular geometry teaching.
17. I intend to use VR to make lessons more stimulating.
18. If I had the opportunity, I would like to use VR in the future for my students.

System usage
19. I will use VR to teach molecular geometry.
20. Using VR can help me for teaching molecular geometry.
21. Using VR is satisfied for teaching molecular geometry.

Appendix II

Virtual reality technology in molecular geometry

Facilitation
1. Make comprehension easier.
2. Make notion memorisation easier.
3. Make notion application easier.
4. Allow people to learn fast.
5. Allow persons to learn with no effort and/or in an implicit way.
6. Make notions convincing.

Motivation/Impact
7. Are suitable for persons who get bored very quickly.
8. Support or enhance motivation.
9. Induce persons to be active.

Rapidity/Intuition
10. Facilitate persons who have an intuitive style of thinking.
11. Allow people to check immediately what have learned.
12. Facilitate persons who have quick reflexes.

Creativity
13. Facilitate people who have much imagination.
14. Stimulate people to be creative.
15. Are appreciated by people who like adventures.
16. Require imagination.

Logical–analytical thinking
17. Are useful to schematise concepts.
18. Facilitate persons who tend to think schematically.
19. Are suitable for logical people.
20. Require to plan actions.

Global view
21. Induce and/or facilitate people to make comparisons and links.
22. Help persons to have a global overview.
23. Require to retain the overall picture.
24. Require to think simultaneously about various things.

Negative effects
25. May be too involving.
26. Are tiring.
27. May be confusing.