Online Science Education Journal http://dergipark.gov.tr/ofed

2020; 5(1): 1 - 8.

Effects of 3D Applications in Organic Chemistry Lessons on Preservice Teachers' Spatial Ability

Soner Yavuz*, *Zonguldak Bülent Ecevit University, Ereğli Faculty of Education*
Cem Büyükekşi, *Zonguldak Bülent Ecevit University, Ereğli Faculty of Education*
Özgür Murat Çolakoğlu, *Zonguldak Bülent Ecevit University, Ereğli Faculty of Education*

*Corresponding Author: yavuz@beun.edu.tr

To cite this article: Yavuz, S., Büyükekşi, C. & Çolakoğlu, Ö. M. (2020). Effects of 3D applications in organic chemistry lessons on students' spatial ability. *Online Science Education Journal*, 5(1): 1-8.

Article Info

Article History

Received:
31 December 2019

Accepted:
12 April 2020

Keywords

Spatial ability
3D pen
3D printer
Organic chemistry

Abstract

Chemistry lessons, especially organic chemistry lessons, require basic skills to imagine and mentally rotate 3D and 2D objects. These skills are related to spatial ability. For meaningful learning, students should have enough spatial ability and teachers should consider to develop students' spatial ability. Spatial ability could be developed permanently by activities and training. 3D printers and 3D pens could be effectively used to design and apply such activities. This research is conducted to analyze the effect of 3D applications on Elementary Science Education students' spatial ability in Organic Chemistry lessons. Organic molecule models were designed and printed in 3D printers. The molecules were used in Organic Chemistry lessons to show coordination of atoms. Also the students draw 3D molecule structures by using a 3D pen. The Purdue Visualization of Rotation Test was administered as pretest and posttest to analyze spatial ability level of the students. The result of the study shows that; traditional Organic Chemistry lessons have no significant effect on spatial ability development; however, 3D applications have significant effect on spatial ability development.

INTRODUCTION

Organic chemistry could be identified as the chemistry of carbon compounds and carbon is an essential element for all living organisms on earth (Solomons, 1990). Stereochemistry is a key element to comprehend organic compounds (Kurbanoğlu & Taşkesengil, 2002). Difficulties in learning stereochemistry could become an obstacle in organic chemistry education (Barta & Stille, 1994) and teachers should be aware of these difficulties and should look for methods to overcome the difficulties.

Drawing molecule structures became very easy by the help of software such as ACD / Chem Sketch (Akpolat & Kartal, 2009). Besides, virtual reality and online communication facilitate people to create and share three dimensional (3D) objects (Hai, 2010). Technological developments provide unlimited opportunities by distance education, simulations and visualization of scientific phenomena. International educational institutions and educators consider the potential of 3D virtual environments that support a place to work in a group regardless of the location (Dalgarno & Lee, 2010). 3D simulations have positive effects; however, it does not give tangible products. 3D printers close this gap. 3D printers convert virtual objects to real objects. Actually 3D printers not only print but also 'make' objects. Products of 3D printers are just limited to imagination. All chemical molecules could be constructed by 3D printers.

Chemistry deals with atoms, molecules and their orientation in space. For this reason, it is inevitable to consider spatial ability for chemistry education. Spatial ability has an effect on students' organic chemistry achievement. Students, who have high spatial ability scores, are more successful on complex multiple-step problems that require problem solving skills and mental manipulation of objects, however, spatial ability has no significant effect on solving some organic chemistry problems, which could be solved by a simple algorithm (Pribyl & Bodner, 1987). Organic chemistry courses include spatial visualization processes, and students, who have low spatial ability, may not able to perform such processes (Supasorns, Suits, Jones & Vibuljan; 2008).

Spatial ability is a cognitive measure and could be examined by tests. Spatial ability tests measure participant's performance on the rotation of 2D objects and 3D objects in space. These tests are mainly three types regarding test administration time. Power test measures ability in enough time to complete, and speed test measures ability in a limited time. Third type is speeded test is a kind of combination of power test and speed test and it is administered in a limited time (Lu & Sireci, 2007).

Activities and training could help to improve spatial ability, and medium term applications make this improvement permanent (Terlecki, Newcombe & Little, 2008). Technological developments facilitate the use of beneficial activities. 3D printers and 3D pens are technological tools to diversify learning environments. Teachers could utilize 3D printers and 3D pens for developing activities and students could make training by 3D objects to develop spatial ability.

The main research question of this research is; "What is the effect of 3D applications on students' spatial ability?". Beside that, another research question is posed as "Is there any effect of organic chemistry lessons on students' spatial ability?".
The results of the study may highlight the importance of 3D applications and reveal the effect of 3D applications on spatial ability development.

Methodology of Research

Quasi-experimental research with nonequivalent groups design was conducted to examine the effect of 3D applications on students' spatial ability. For this purpose, students designed organic molecules, such as nitrobenzene, acetylsalicylic acid etc., and they draw by using a 3D pen in one semester. Also fundamental organic molecule structures were constructed by 3D printer and these molecules were used in Organic Chemistry lesson spring semester in the 2016-2017 academic year.

Sample of Research

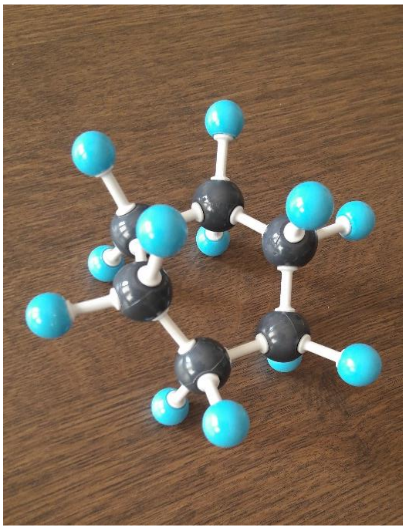
Sample of research is 80 2nd grade level Elementary Science Education students in Ereğli Faculty of Education, at Zonguldak Bülent Ecevit University. Only accessible and available students participated in this study, so convenient sampling is used in the sampling procedure. Data were collected in the 2015-2016 academic year and 2016-2017 academic year. 40 2nd grade level Elementary Science Education students in the 2015-2016 academic year were assigned as control group and 40 2nd grade level Elementary Science Education students in the 2016-2017 academic year were assigned as experimental group. All students in this study were assigned to Organic Chemistry lessons. The Purdue Visualization of Rotation Test was administered to students at the beginning of the study. Spatial ability levels of the experimental and control groups are not significantly different (Table 1.)

The experimental group and the control group did not practice in the same semester. Both the control group and the experimental group members studied the same curriculum in a smiliar context, so extraneous variables, such as context, effect of lecturer, effect of course loading, were assumed identical.

Instrument and Procedures

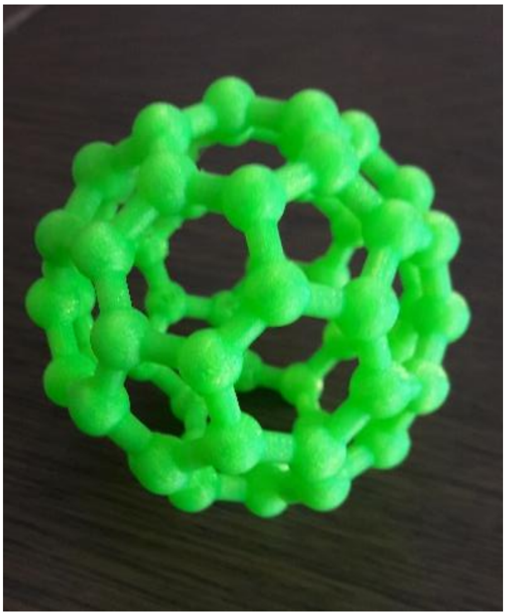
Data collection instrument of the research is The Purdue Visualization of Rotation Test. The test was developed by Guay (1976) and it was revised by Yoon (2011). Test has 30 items and it is aimed to measure spatial ability in 3D mental rotation in a limited time. Time limit was 20 minutes for both pre-test and post-test application. In order to check internal consistency, Kuder-Richardson reliability coefficient was calculated and found as 0,73.

The Purdue Visualization of Rotation Test was administered to both the control group and the experimental group as pretest at the beginning of semester and posttest at the end of the semester.

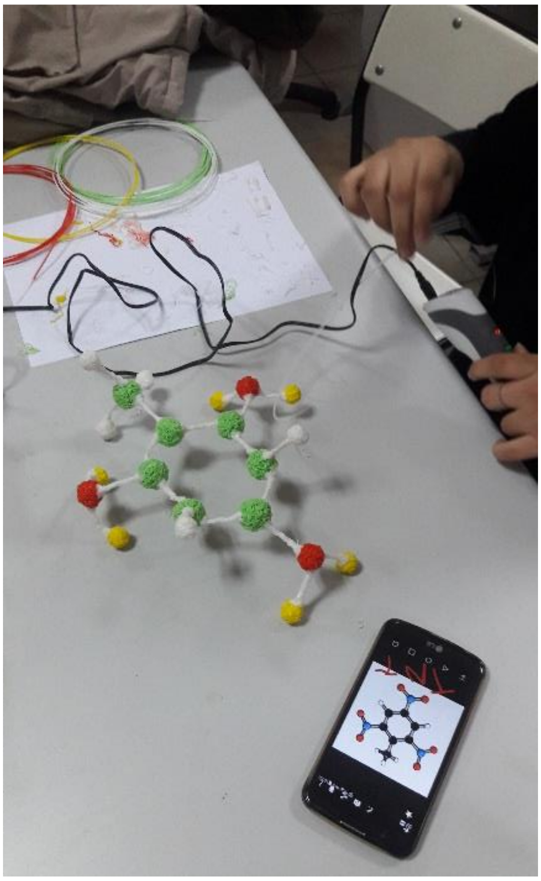


Picture 1. Balls and sticks model

Any special teaching method was not applied in the control group. The students in the control group just used molecular model kits involving balls and sticks. The molecular model kit, which consists of balls and sticks, is easy to operate and students do not need to spend a long time constructing a molecule (Picture 1.). Besides this, the kit is limited to construct only simple molecules.

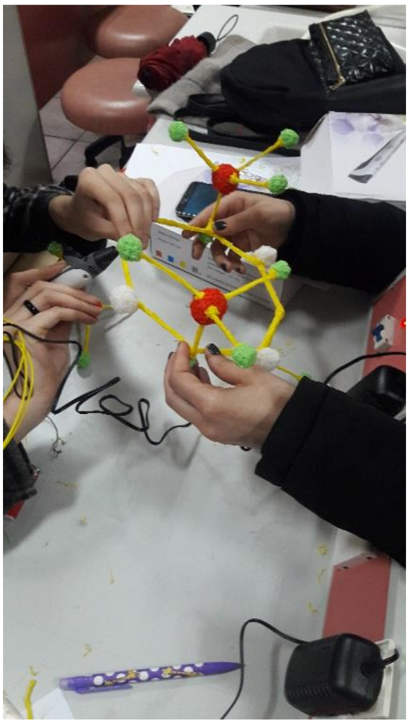


Picture 2. Molecule model constructed with 3D printer



Picture 3. Molecule model constructed with 3D pen

The control group lessons were supported by 3D printed organic molecules (Picture2.). They designed and built organic molecules by using 3D pens (Picture3. and Picture 4.). They were not familiar with 3D pens but it is easy to operate. The students were aware that unlimited molecules could be constructed.



Picture 4. Students are constructing molecule model with 3D pen

Data Analysis

Normality assumption of all pretest scores of control and experimental group were analyzed with Kolmogorov-Smirnov test (p>0,05). Kolmogorov-Smirnov test checks scores whether distribution of scores deviate from normal distribution (Field, 2013). According to results, parametric statistics methods were conducted. Data were analyzed in SPSS package program by independent t-test and paired t-test in 95% confidence interval.

RESULTS

An independent samples t-test was conducted to compare scores of the control group and the experimental group. There is no significant difference in The Purdue Visualization of Rotation scores of the experimental group (M=11,88, SD=4.58) and the control group (M=12,38, SD=3,99), t(78)=0,52, p=0,60 (Table 1.).

Table 1. Independent t test scores of The Purdue Visualization of Rotation Test

	N	M	S.D.	df	t	p
Experimental Group	40	11,88	4.58	78	0,52	0,60
Control Group		12,38	3.99			

Table 2. Paired t test scores of control group

	N	M	S.D.	df	t	p
Pre-test	40	12.38	3.99	39	0,94	0,35
Post-test		13.00	4.96			

A paired-sample t-test was conducted to compare the control group's pretest scores and posttest scores. There is no significant difference between pre-test scores (M=12,38, SD=3,99) and posttest (M=13,00, SD=4,96) scores; t(39)=0,94, p= 0,35 .

Table 3. Paired t test scores of experimental group

	N	M	S.D.	df	t	p
Pre-test	40	11.88	4.58	39	2.92	0,01
Post-test		13.30	5.40			

A paired-sample t-test was conducted to compare the experimental group's pretest scores and posttest scores. There is significant difference between pretest scores (M=11,88, SD=4,58) and posttest (M=13,30, SD=5,40) scores; t(39)=2,92, p= 0,01 .

DISCUSSION AND CONCLUSION

The experimental group and the control group were assumed as identical because they were studying at the same department and same grade level. Also spatial ability levels of the experimental group and the control group were not significantly different (Table 1.). There were two expected variables which affect spatial ability; Organic Chemistry lessons and 3D applications. Analysis of the control group's pretest and posttest scores (Table 2.) revealed the effect of Organic Chemistry lessons on spatial ability. The control group's spatial ability scores had increased but there was no significant difference. So we argue that traditional Organic Chemistry lessons performed by lecturing have no significant effect on spatial ability development. Similarly, Salkind (1976) stated the deficiency of traditional teaching to develop spatial ability. Organic chemistry course involves mental manipulation of 3D objects, but this course is not enough to develop spatial ability without appropriate activities. 3D diagrams are a part of Organic Chemistry lessons but as Huang & Lin (2017) stated; just figuring 3D images in students' minds has only a limited impact on spatial visualization. Omar & Mozol (2020) have reported the positive effect of 3D applications in Chemistry classes on spatial ability. They conducted an experimental study to test effectiveness of technological aids and 3D materials. The results revealed the 3D materials' superiority over technological aids. We can conclude that 3D materials, rather than 3D images, could help to improve spatial ability.

The main research question was tested by analyzing pretest scores and posttest scores of the experimental group (Table 3.). This result reveals the positive effect of 3D applications on students' spatial ability. The control group had also used molecular models, but they did not use their creativity and they did not spend a long time. Because molecular model sets are limited to construct basic molecules and it is too easy. The Students, who are using 3D pens, are not limited by tools. On the contrary, dealing with a 3D pen and spending time by creating molecules motivates them. Molecular model sets are intended to create molecules without error and it prevents the development of students' spatial ability. On the other hand, students creating molecules by 3D pen have the possibility to make errors. They could notice the error and learn the cause of error.

Students should have accurate and realistic imagery to have a robust idea about visualization (Olkun & Uçar, 2007). Molecular model sets provide accurate and realistic imagery, but it is not sufficient to develop spatial ability. Activities based on spatial training help to develop spatial ability (Owens & Clements, 1998), but appropriate materials should be used in such activities (Olkun & Altun, 2003). Molecular model sets are not enough to develop spatial skill, because these sets are designed to create just molecules. Students do not have to manipulate figures. On the other hand, 3D pens are not designed to draw just specific objects. Students have to design molecules mentally and give decisions about processes. So students engage more mentally active when building molecules with 3D pens, compared to building molecules with molecular model sets.

Chemistry courses, especially organic chemistry, deal with atoms, molecules and their orientation in space. Students should be able to imagine molecules orientation and also rotations in space. Besides, chemistry includes concrete and abstract phenomena. Abstract phenomena could be transformed into concrete phenomena by visualization. These facts highlight the importance of spatial ability, so students' spatial ability should be improved. 3D applications have a positive effect on spatial ability development. 3D applications could be integrated into the curriculum not only in Organic Chemistry but also other courses involving models and figures. In order to improve spatial ability, activities with 3D materials are superior over just dealing with images. Similarly, creating 3D objects is superior over performing activities with pre-built 3D materials.

ACKNOWLEDGEMENT

This study was funded by Zonguldak Bülent Ecevit University Personal Research Project; Investigation The Effect of 3D Applications (3D Printer Pen) Toward Students' Chemistry Motivation and 3D Perceptions in Organic Chemistry Lesson. Project Number: 2016-62601546-01

REFERENCES

Akpolat, O. & Kartal, F. (2009). Kimyacılar için bilişim teknolojileri, *Akademik Bilişim'09 - XI. Akademik Bilişim Konferansı Bildirileri,* 11-13 Şubat 2009 Harran Üniversitesi, Şanlıurfa.

Barta N.S. & Stille, J.R. (1994). Grasping the concepts of stereochemistry. *Journal of Chemical Education, 71(1)*, 20-23.

Dalgarno, B. & Lee, M. J. W. (2010). What are the learning affordances of 3d virtual environments?, *British Journal of Educational Technology,* 41*(1),* 10-32.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics*. Sage.

Guay, R. B. (1976). *Purdue spatial visualization test*. West Lafayette, IN: Purdue Research Foundation.

Hai-Jew, S. (2010). *Virtual Immersive and 3d Learning Spaces: emerging technologies and Trends.* USA: Igi Publishing.

Huang, T. C., & Lin, C. Y. (2017). From 3d modeling to 3d printing: development of a differentiated spatial ability teaching model. *Telematics and Informatics, 34*(2), 604-613.

Kurbanoğlu, N & Taşkesenligil, Y. (2002). *Organik kimyada stereokimya konusunun programlı öğretimi*, V. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi, 16-18 Eylül 2002, ODTÜ.

Lu, Y., & Sireci, S. G. (2007). Validity issues in test speededness. *Educational Measurement: Issues and Practice, 25(4),* 29-37.

Olkun, S., & Altun, A. (2003). İlköğretim öğrencilerinin bilgisayar deneyimleri ile uzamsal düşünme ve geometri başarıları arasındaki ilişki. *The Turkish Online Journal of Educational Technology*, 2(4), 86-91.

Olkun, S.& Uçar, Z. T. (2007*). İlköğretimde etkinlik temelli matematik öğretimi*. Ankara: Maya Akademi.

Omar, K., & Mozol, V. (2020). Exploring the role of viewing technologies in the chemistry classroom. *Papers on Postsecondary Learning and Teaching, 4,* 68-75.

Owens, K. D., & Clements, M. K. (1998). Representations in spatial problem solving in the classroom. *The Journal of Mathematical Behavior*, *17*(2), 197-218.

Pribyl, J. R., & Bodner, G. M. (1987). Spatial ability and its role in organic chemistry: a study of four organic courses. *Journal of research in science teaching, 24*(3), 229-240.

Salkind, N. J. (1976). A cross-dimensional study of spatial visualization in young children. *The Journal of genetic psychology*, *129*(2), 339-340.

Solomons,T.W.G. (1990). *Organic chemistry*. New York: Wiley.

Supasorn, S., Suits, J. P., Jones, L. L., & Vibuljan, S. (2008). Impact of a pre-laboratory organic-extraction simulation on comprehension and attitudes of undergraduate chemistry students. *Chemistry Education Research and Practice, 9*(2), 169-181.

Yoon, S. Y. (2011). *Psychometric properties of the revised purdue spatial visualization tests: visualization of rotations (The Revised PSVT: R)*. Purdue University.

Terlecki, M. S., Newcombe, N. S., & Little, M. (2008). Durable and generalized effects of spatial experience on mental rotation: Gender differences in growth patterns. *Applied Cognitive Psychology*, *22*(7), 996-1013.