MULTIMEDIA VS CONCRETE MODEL: REVIEW OF STUDIES EMPLOYING THE TOOLS IN CHEMISTRY TEACHING

Rooserina Kusumaningdyah, Habiddin Habiddin*, Yudhi Utomo

Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang
Jl. Semarang No. 5 Malang, Indonesia

Abstract –This paper describes previous studies regarding the use of multimedia or virtual model and concrete model to improve students' understanding of chemistry. Thirty-three relevant papers in various topics, including stereochemistry, symmetry, chemical bonding, law conservation of matter, and others, were found and discussed. In particular, relevant studies in stereochemistry teaching is also discussed.

Keywords: *Multimedia, Concrete Model, spatial ability, 3D orientation, stereochemistry*

INTRODUCTION

Representation or manipulatives tools are among the most important technologies for learning at many levels. It is considered that manipulative tools can assist students in perceiving, understanding, and manipulating three-dimensional spatial relationships. For this reason, many education researchers have give a lot of effort into the refinement, development, and implementation of such tools (Stieff et al., 2005). Manipulative tools are widespread in many chemistry topics, particularly visuospatial aspects and space orientation such as stereochemistry, symmetry, and other relevant topics.

Manipulative models can be used to assist students in understanding abstract concepts and as instructional tools during learning. Several researchers, including Dayame (2019), suggest that this manipulative model can significantly improve student learning outcomes. Several manipulative models include hand-held, concrete, and multimedia models such as computer simulations (Kirk, 2015). The manipulatives tools are essential in enhancing students to achieve good performance in stereochemistry (Stull et al., 2012; Stieff et al., 2016; Knowles, 2017).

Today, efforts to improve the quality of technology-driven learning have attracted the interest of educators and the wider community. One of the interesting features of the technology is the application of multimedia. A multimedia tool or material can combine several elements in one package, namely text, images, animation, video, interactivity, and others. Multimedia can now improve learning outcomes (Chen & Catramchenbone, 2014). Several chemistry learning experts have innovated to develop learning multimedia, including Sentongo et al. (2013), Chen et al. (2013), and Lou & Lin (2012), and specializing in stereochemistry: da Silva et al. (2017), Harrold (1995), and SeviNç (2010). In many circumstances, the virtual laboratory has been employed in laboratory chemistry (Hakim et al., 2020; Muchson et al., 2019).

The developed learning multimedia is designed to display chemical material supported by multi-concept representations in two-dimensional visualization, three-dimensional virtual models presented in molecular modelling programs and animations in videos and games. For example,

*Corresponding author: Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang. Jl. Semarang No. 5 Malang, Indonesia. Email: Habiddin_wuni@um.ac.id

multimedia is designed to illustrate difficult concepts such as chemical equilibrium. Concrete models have the advantage that students can physically interact with the models and see them in three dimensions. The advantages of virtual or multimedia media are that the bond length, bond angle, and valence are unlimited and manipulated. In addition, the advantages of virtual/multimedia models are that they are more cost-effective and do not require much time to construct other molecular models (O'Brien, 2016).

METHOD

This study employed a literature review of multimedia and concrete model articles. The literature review discussed previous research on multimedia and concrete model effectiveness in chemistry teaching and beyond. The details of the articles studied are provided in Table 1.

Table 1. Reviewed Articles

No.	Authors (Year)	Notes	Publication
1.	Anggriawan (2017)	Multimedia and students' understanding of symmetry	<i>Master thesis</i>
2.	Beauchamp (1984)	Bodyparts (arm and fingers) and chiral centres: stereochemistry	<i>International journal</i>
3.	Chen et al. (2013)	Multimedia technology in a chemistry laboratory	<i>International journal</i>
4.	Chen & Catrambone (2014)	Multimedia Interactivity and spatial ability	<i>International journal</i>
5.	Da Silva et al. (2017)	Computer game and understanding of stereochemistry	<i>International journal</i>
6.	Dori & Barak (2001)	Virtual and Physical model: Understanding of organic chemistry, Model Perception and Spatial Understanding.	<i>International journal</i>
7.	Harrold (1995)	Molecular modelling & stereochemistry	<i>International journal</i>
8.	Hakim et al. (2020)	Virtual vs real laboratory	<i>National accredited journal</i>
9.	Thayban et al. (2021)	Virtual and concrete model in chemistry teaching: review	<i>National accredited journal</i>
10.	Thayban et al. (2021)	Virtual and concrete model & understanding of symmetry	<i>International journal</i>
10.	Kirk (2015)	Manipulatives Tool & Understanding of the Law of Conservation of Matter	<i>Master Thesis</i>
11.	Knowles (2017)	Eye-Tracking and Molecular Modelling	<i>PhD Thesis</i>
12.	Koutalas et al. (2014)	2D Molecular model & spatial ability	<i>International proceeding</i>
13.	Lou & Lin (2012)	Multimedia	<i>International journal</i>
14.	O'Brien, M. (2016)	3-D & Stereoselective Reaction Pathways	<i>International journal</i>
15.	Olimpo et al (2015)	2D & Translation ability	<i>International journal</i>
16.	Sentongo et al. (2013)	Computer Simulations & Chemical Bonding	<i>International journal</i>
17.	Sevi (2010)	Computer Simulations & Chemical Bonding	<i>Conference proceeding</i>
18.	Stieff et al. (2005)	Visualization tool	<i>Book chapter</i>
19.	Stieff et al (2016)	Concrete Model & Representational Competence	<i>International journal</i>
20.	Stull et al. (2013)	Concrete and Virtual Models	<i>International journal</i>
21.	Stull et al (2012)	Concrete model & representational Translation	<i>International journal</i>

The articles were selected based on matching with “concrete model, virtual model, spatial ability, virtual model” keywords. All of the terminologies covers the area of models and modelling in chemistry. Some related articles in the non-chemistry area were also found searching the articles. However, we limited our review to chemistry-related teaching only for avoiding excessive work.

RESULTS AND DISCUSSION

As presented in Table 1, the use of virtual models and concrete models in chemistry teaching have been popular and published in many international journals and international proceedings. However, those published in national accredited journals are limited. In national accredited journals, we found an article reviewing the role of concrete and virtual models in students’ chemistry understanding (Thayban et al., 2020). We realize that the procedure applied in this review may not cover all the relevant studies published in Indonesian accredited journals. Therefore, it will sound too ambitious to build a general claim. However, this may indicate that such study in this area is still not widely explored in Indonesia.

Studies regarding virtual and concrete models have been well known internationally. Such studies have been published in many journals and international proceedings, including highly reputable journals such as science education, chemistry education research and practice and journal of chemical education. Thayban et al. (2021) described the role of virtual and concrete models in symmetry teaching and revealed that the virtual model demonstrated a higher contribution than the concrete model. 2D representation influenced students’ success in translating from one representation to another in organic chemistry courses (Olimpo et al., 2015). This fact indicates that a novel, up-to-date, and progressive approach should be employed for similar studies to be accepted in reputable journals.

The use of concrete models has been done for a long time. In the 1940s, Pitzer and Hazel won the Nobel Prize in chemistry for demonstrating the axial and equatorial forms of the seat conformation of the cyclohexane ring using a concrete model. Molecular models such as space-filling 30 years later became an indispensable tool because they can help predict conformational structure, stereochemistry, reactivity and physical properties in organic chemistry (Dori et al., 1999). Sachse, one of the chemists, also uses molecular models to predict the shape of the “boat” and “chair” conformation of cyclohexane. A study was also conducted by Boukhechem et al. (2016) to determine to what extent concrete models or molymods can develop students’ abilities in translating and coordinating between 2D to 3D representations and vice versa in Stereochemical topics. Examples of the representation are the Newman projection, the Fischer projection, and the dimensional formula, as shown in Figure 1.

Figure 1. Some forms of Stereochemical Representation (Source: Boukhechem, 2016)

These stereochemical representations require students to construct, identify, interpret, and coordinate the differences between these representations (Stull et al., 2012). Rajee and Stieff also stated that students with weak reasoning skills would find it difficult to identify the correlation

between conformational differences and the energy differences of each conformation molecule (Stieff et al., 2016).

Concrete models have the advantage that students can physically interact with these models and see them in three-dimensional form (O'Brien, 2016). Real models can also visualize the transition state of stereoselective or diastereoselective reaction mechanisms. To a certain extent, using real models with this approach is more difficult because the molecules need to be held in place by hand. This means that overlay drawing cannot be done simultaneously and necessitates recording a video of the manipulation first, then creating a new one with the annotation added. This could be alleviated if some clamping mechanism was used to hold the model steady whilst the overlaid line diagram was drawn.

Figure 2. Use of physical models (Molymod). A) Transition-state structure made with Molymod system manipulated, using a webcam to make a video. B) Video played and paused to show a particular viewpoint. (Source: O'Brien, 2016)

Relative Effectiveness of Multimedia and Concrete Model on Enhancing Conceptual Understanding in Stereochemistry

Many studies have been carried out to compare the relative effectiveness of multimedia and concrete models. However, the finding result shows that some studies revealed that multimedia had outperformed the concrete model. On the other hand, several studies also found that the concrete model is more appropriate to be implemented on a typical certain learning process. Olkun (2003) stated that both computer and concrete positively affect students' geometric reasoning about two-dimensional geometric shapes, especially on spatial tasks. Although the positive trend is obvious and the computer group gained relatively more from the intervention than the concrete group, the overall difference between the experimental groups (concrete versus computer) was not statistically significant.

Therefore, the choice between computer versus concrete manipulatives is not very clear. Both computer and concrete positively affect students' geometric reasoning about two-dimensional geometric shapes, especially on spatial tasks. Although the positive trend is obvious and the computer group gained relatively more from the intervention than the concrete group, the overall difference between the experimental groups (concrete versus computer) was not statistically significant. Meanwhile, Dori & Barak (2001) promoted multimedia and concrete media during the learning process in chemistry. It is objected that multimedia can overcome the limitless of the concrete model and vice versa, so both of them complement each other.

It was also revealed that the accuracy for both model types was high and did not differ between the two model types, multimedia and concrete model. This suggests that multimedia models can offer the same benefits for teaching chemistry instructions as concrete models. More importantly, because they are digital, they can be delivered to more people and more rapidly across the internet and ubiquitous technologies such as smartphones tablets. In addition, they can be integrated more easily into e-learning resources such as online learning, ebooks, digital tutorial systems, customized to service individual needs, and programmed to behave in task beneficial

ways (Stull et al., 2013). So it is related that multimedia has more beneficial than concrete media based on its availability, efficiency and flexibility.

O'Brien (2016) also asserts that molecular models, either real or virtual, are extremely useful in aiding students' understanding of stereochemical concepts. The study reveals that multimedia or virtual model has an advantage. The bond lengths, bond-angles and valencies are not restricted in any way. In addition, virtual models are essentially free, assuming free access to a computer, and take no time to re-construct, thus allowing students to swap between several models easily. Furthermore, Abraham and colleagues (Knowles, 2017) also conducted research exploring the relative effectiveness of several kinds of molecular representation on students' understanding of stereochemistry concepts. The resulting study indicates that multimedia or virtual media was the most effective representation type. Nevertheless, the physical model or handled model can also help students learn difficult stereochemistry concepts, and for most, organic chemistry classrooms have no access to computer visualization software.

Meanwhile, Stull et al. (2012) also added several advantages of physical models. One of these advantages is that a physical model can represent the three-dimensional structure externally and give an accurate performance. For example, when doing the rotating task for depicting the 3-D structure of the molecule in the two dimensions. A physical rotation of a model is holistic. Because the model is rigid, it maintains the spatial relations between its components when the whole model is rotated, which can not be demanding on working memory.

CONCLUSION

Our review found that studies employing concrete and virtual models in chemistry teaching may not be very popular in Indonesia except in international areas. The number of relevant studies found in Indonesian journals is limited, but many for international journals. This phenomenon indicates that such a study has been well known internationally. Therefore, to get accepted in an international journal for this study, a progressive approach may be added. However, we realize that this review may sound too ambitious to claim that this result represents the fact. A more comprehensive review involving wider chemistry and science education journals will be further carried out.

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