Using Multiple Representation for Developing Chemistry Understanding Among Chemistry Students at the Faculty of Education

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Abstract

This research aimed to identify types representations which can help students understanding chemistry topics, and investigate the effect of using multiple representations on developing chemistry understanding levels among chemistry department students at faculty of education. So, the instruments of research included Chemistry understanding test, and Semi structured interviews. The sample of study consisted of (N=87) 4th year chemistry department students at Faculty of Education Benha university. The chemistry understanding pre and post- test and Semi structured interviews applied on study group which learned stereochemistry unit by using multi representations. The results of research showed that there is statistically significant difference at 0.05 between the means of the pretest and posttest of chemistry understanding test in favor of post- application. There is statistically significant difference at 0.05 between the means of the pretest and posttest of chemistry understanding levels (symbolic – Macro – Micro – process) in favor of post- application. The qualitative analysis was performed through semi-structured interviews, and analysis of responses students, which indicated the effectiveness using multiple representations on developing chemistry understanding levels.

Keywords: multiple representations, chemistry understanding level.

المستخلـــــص

يهدف هذا البحث إلى تحديد أنماط التمثيلات التي يمكن أن تساعد الطلاب على فهم موضوعات الكيمياء، ودراسة أثر استخدام تمثيلات متعددة في تنمية مستويات فهم الكيمياء بين طلاب قسم الكيمياء في كلية التربية. لذلك، تضمنت أدوات البحث اختبار فهم الكيمياء، والمقابلات شبه المنظمة. تكونت عينة الدراسة من (N = 87) من طلاب قسم الكيمياء بالفرقة الرابعة بكلية التربية جامعة بنها. تم تطبيق اختبار فهم الكيمياء والمقابلات شبه المنظمة قبليا على مجموعة الدراسة التي تعلمت وحدة الكيمياء الفراغية باستخدام التمثيلات متعددة وبعد الانتهاء من دراسة الوحدة تم تطبيق أداتي الدراسة بعدياً. أوضحت النتائج أن هناك فروق ذات دلالة إحصائية عند ٠,٠٥ بين متوسطات درجات التطبيق القبلي والبعدي لاختبار فهم الكيمياء. لصالح التطبيق البعدي. وهناك فروق ذات دلالة إحصائية عند ٠,٠٥ بين متوسطات درجات التطبيق القبلي والبعدي لمستويات فهم الكيمياء (الرمزية – الماكرو Macro – الميكرو Micro – العملية). لصالح التطبيق البعدي. تم إجراء التحليل النوعي من خلال المقابلات شبه المنظمة، وتحليل الإجابات مفتوحة النهاية للطلاب، والتي أشارت إلى فاعلية استخدام التمثيلات المتعددة في تنمية مستويات فهم الكيمياء.

Introduction:

The most significant field of study in chemistry education is the conceptual understanding of chemical representations among the students. In Chemistry, researchers and learners clarified the three levels of representations in it for decades: macroscopic, microscopic, and symbolic. At the macroscopic level, chemical representations are an observable phenomena such as changing matter. The microscopic chemistry is the nature, arrangement, structure and motion of molecules that are used to clarify compound properties or natural phenomena. At symbolic-level chemistry is the symbolic representations of atoms, molecules, and compounds, such as chemical symbols, formulae, and structure.

Experimental researches clarified that understanding symbolic and microscopic representations was difficult for learners as result of they are abstract and invisible where learners depend heavily on sensory knowledge for understanding chemistry. They are capable of chemistry understanding at three levels. The researchers have advanced recent approaches to educate chemistry such as adapting teaching strategies based on the model of conceptual change, submitting a theory's historical change, employing sensory models and technological instruments. Also, multimedia tools that integrate molecular model animation, chemical equilibrium video clips, or real-time graphics offer opportunities for students to visualize chemical processes at the microscopic level.

Kozma et.al clarified that using multiple representations enabled learners grasp the subject of chemical equilibrium in addition to the chemical concepts which are related with it, according to empirical findings from their studies. Research also supported the benefits of manipulating physical models which enable learners visualize both of atoms and molecules in addition to foster understanding for long-term (Wu, Krajcik, & Soloway, 2000, 1).

There were many studies interested in investigating conceptual understanding of chemistry through determine alternative conceptions at chemistry understanding level such as: (Aydin, Aydemir, Boz, Cetin-Dinar, & Bektas, 2009), (Avci, Acar Şeșen, & Kirbaşlar, 2014), (Brandriet, 2014), (Dangur, Avargil, Peskinb, & Dori, 2014), (Versprille, 2014), which indicated that there was difficulty in understanding chemistry. while were many studies interested in developing chemical understanding levels (Macro – Micro – symbolic – process) such as (Barak & Dori, 2004), (Dori, & Sasson, 2008), (Chanin, 2012), (Seung, Choi, & Pestel, 2016), (Srisawasdi, & Panjaburee, 2019) which confirmed interest in developing chemistry understanding.

Thus, there are many studies seeks to developing chemistry understanding. Some of them used multiple representations to developing chemistry understanding levels such as (Wu, Krajcik, & Soloway, 2000) which used visualizing tool eChem, (McDermott & Hand, 2013) which integrated multiple modes of representation modes to learn activities at the end of the unit writing, (Jaber, & Boujaoud, 2012) which used a macro – micro – symbolic teaching approach based on contructivist, (Ibrahim, Surif, Abduallah, Ali & selamat, 2014), (Al-Balushi & Al-Hajri, 2014), (Daubemmire, 2014), (Shen, 2015), (Lansangan, Orleans, Marie, & Camacho, 2018), (Derman, Koçak, & Eilks, 2019), (Baptista, Martins, Conceição & Reis, 2019).

Problem of the Study

Problem of research involved difficult of chemistry understanding among education college students department of chemistry which was revealed through unconstitutional interviews with staff and some students as well as the test result, and to solve that research attempted to solve these questions.

Question of the Study

- What is multi representation can employed in chemistry themes?
- What is the effect of using multiple representation in chemistry for developing understanding among students at faculty of Education.?

Aims of research

The research aims to:

- Identify types representation which can help students understanding chemistry topics.
- Use multiple representations in teaching chemistry
- clarify the impact of using multiple representation for developing chemistry understanding

Significance of research

- Research provide list of multi representation that can using in chemistry and especially in stereochemistry, which can use by chemistry teacher for teaching chemistry and learner to understand chemistry.
- Helping chemistry teacher in building chemistry understanding test.
- Helping curriculum developer concentration (focus) on employing multi representation in chemistry curriculum.
- Helping curriculum developer concentration (focus) on teaching chemistry at symbolic, macro, micro, and process level.

Delimitations of the research

- The research was applied on group of chemistry department students at faculty of education, Benha university at 4th year

Instruments of the research

- Chemistry understanding test.
- Semi structured interviews

Hypotheses of the research

- There was no statistically significant difference at 0.05 between the means of the pre - test and those of the post – test of chemistry understanding test.
- There was no statistically significant difference at 0.05 between the means of the pre- test and those of the post – test of chemistry understanding levels (symbolic – Macro – Micro – process).

Literature Review and Related Studies

Chemistry and Representations:

Chemistry representations are models, metaphors, and theoretical constructs of the interpretation of reality and nature by the chemists. Therefore, chemical representations seem to be meaning – based representations of information that are altered and produced to indicate the reconstruction or reunification of the experimental and the theoretical. furthermore, chemical representations are characterized with First, the chemical representations are appropriate models for specific purposes such as the representation of physical position of atoms and molecules by ball-and-stick models, also information on the size of atoms which important to decide organic molecules' conformation can be provided through space-filling models. Therefore, representations implicate elected specifics of relevant principles or concepts, but allow to vanish other specifics. Second, the creation of representations shows the theories historically evolving through examining the evolution of the method in which the chemists see and draw. **(Wu, Krajcik, & Soloway, 2000, 2, 3**)

Gabel, Samuel and Hunn (1987) suggested this historical development that most chemistry definitions have three stages of understanding: tactile, symbolic and particulate stages. Chemists turn sensory knowledge into chemical processes, describe such processes as particulate-level atomic and molecular actions, and translate atoms and molecules into symbols and formulas. Thus, one source of learning difficulties of students is the abstract and theoretical nature of representations. Third, chemistry representations are signs, symbols, or elements of the chemical language and world-view vehicles. Hoffmann and Laszlo (1991) claimed that a chemical formula is like a word that comprises the language of chemistry and aims to identify, the chemical species it stands for. **(Wu, Krajcik, & Soloway, 2000, 3**)

The significant indicator of that comparison is that the role of communication is performed by both language and chemical representations. Kozma, Chin, Russell and Marx (1997) found in their ethnographic research at a chemistry laboratory that representations are used to interact with one another and to recreate nature and reality by the chemists. They utilize diverse representations to raise questions, state assumptions, make statements, draw inferences and reach conclusions **(Wu, Krajcik, & Soloway, 2000, 3**).

It is necessary to acquire experience, In order to be familiar with the representations in addition to its use in chemistry. Kozma (1997) revealed that using and comprehension a range of representations is not just a significant component of what chemists do — it really is chemistry in a profound sense. Kozma and Russell (1997) showed that Chemistry instruction would therefore enhance students' representation competence **(Wu, Krajcik, & Soloway, 2000, 3**)

It can be noted that Chemistry education provides opportunities for students learn how to use representation in an appropriate way. In spite the essential role representations in chemistry, however, many students face difficulties in visualizing them. Several students' chemistry understanding is clarified by the perceptual experiences from daily life. Students try to be in the sensory level and disable to visualize particulate behavior and symbolic representations **(Wu, Krajcik, & Soloway, 2000, 2**).

Representation in Chemistry

Understanding chemistry focused on usage representations to describe unseen processes and objects. Chemists therefore create representational systems between something which they can see and something they cannot see. For chemists' practice, fluency in usage and transition between various representational formats is necessary. An incapability to effectively use multiple forms of representing scientific ideas together with an incapability to comprehend the usefulness of the efficient usage of multiple modes to represent a single scientific concept can eventually hinder the ability of learners to develop a rich conceptual understanding of the scientific ideas they are studying **(McDermott, & Hand, 2013, 218).**

The difficulties students face in learning about chemistry ranged from human factors to the chemistry's internal nature of the chemistry. In order to improve the comprehension of chemistry among learners, there is broad agreement within the association of chemistry educators regarding its significance and the need to incorporate various levels of representation into the tools of chemistry instruction. **(Upahi, & Ramnarain, 2019, 146)**.

Understanding molecular properties and processes has been a difficulty, largely because the direct understanding of molecules and their properties is not available. Thus, Chemists have built instruments and representational systems that mediate between what they cannot see and what they do see. Chemists use representations and resources within a culture of common interests, expertise, and debate to explain, anticipate, and modify the chemical processes that are the focal point of their research. **(Kozm, Chain, Russell& Marx, 2000, 106, 107).**

This situated mediational process has two significant interrelated aspects: the material and the social. Firstly, it clarified the surface characteristics of physical objects as well as abstract images, characteristics that can be interpreted and manipulated. Secondly, it underlines the inherent semiotic and rhetorical process through which chemists claim representations represent unseen entities and processes through representation. If this relationship is formed, scientists may reason with the physical characteristics of representations to draw inferences regarding phenomena that are not adequately explained utilizing their surface characteristics alone **(Kozm, Chain, Russell& Marx, 2000, 106, 107).**

Students must learn concepts in chemistry which are inherently visuo-spatial. Chemistry teaching appears to rely heavily on the use of graphical representations to make certain principles available to students. Graphical representations are instructional materials that illustrate specific domain concepts (as opposed to text or symbols) using visuo-spatial elements. In addition, graphical representations are essential instrument used by chemists to solve problems, think and, in other words, for communicating, graphic representations are an integral part of the Chemistry Discipline's discourse. Representative competencies are also essential to the learning of students in chemistry. Representative competencies are also essential for the learning of students in chemistry. In particular, the learning success of the students depends on their ability to connect between graphic representations **(Rau, 2015, 654).**

Wu and Shah (2004) clarified the main principles that helped learners understand the concepts of chemistry and improve and visuo spatial thinking representational skills. Which involve (1) showing the same details to students in a wide variety of formats and descriptions; (2) allowing clear linkages between representations to help students to establish logical connections from these various representations; (3) illustrating the complex and interactive nature of chemistry; and (4) promoting transition among 2D and 3D. Mayer (2002) defined learning processes as learners use pictures and words based on three assumptions. People utilize the visual-pictorial channel and the auditory-verbal channel, both channels may get overwhelmed if so many words and images are used in learning and meaningful learning happens while the learners are fully engaged and interpret their learning through the practice of both channels. Computer based visualization instruments and computerized molecular modeling can aid learners enhance their ability to create 2D-3D transformations. This skill, in effect, will help students gain understanding of chemical concepts **(Dangur, Avargil, Peskinb, & Dori, 2014, 299)**

Visualization allows for the development of a richer collection of principles when it comes to quantum theoretical concepts. It may too be used to identify mental models of students about the particulate nature of matter and atoms and molecules while investigating illustrations of students. In particular, simulation will enhance students ' understanding of the form and size of the atom and of the probabilistic existence of the atomic orbitals **(Dangur, Avargil, Peskinb, & Dori, 2014, 299).**

Johnstone (1991) initially suggested the "triplet relationship" as a way to represent ideas of students with phenomena in chemistry. The triple relationship has been updated in the following twenty years to include 1) macroscopic (observable properties such as colour, feel, state), 2) submicroscopic (e.g. molecular and atomic levels) and 3) Symbolic representations (formulae and equations). Daubenmire (2014, 1) presented the following figure that others also argued that graphs and tables of data should be used as representations.

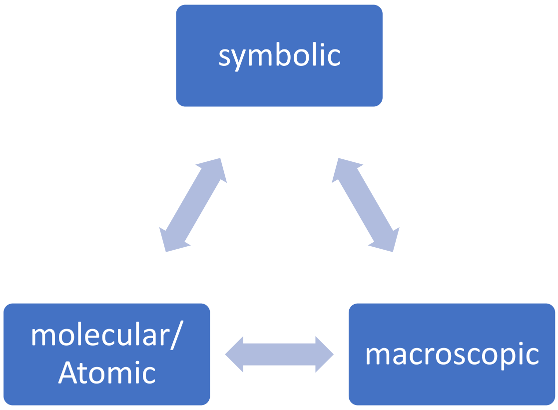

Figure (1) The Triplet Relationship adapted from Daubenmire (2014, 1)

Chemistry learners, on the other hand, frequently can't understand the symbolic representation that usually represented as a chemical structure or collection of chemical symbols. Also, the traditional chemistry curriculum did not enhance atomic-level understanding of concepts but focused on algorithms instead. The means or bridge to connect between the molecular representation and the observable macroscopic representation should be considered symbolic representations. If learners spend a lot of time memorizing chemical symbols, the essence of what those symbols represent is missing. Interestingly enough, the visual representation merely explains what is happening with these other two views in equations, emotions, and symbols. (There might even be a didactic value in calling them 'views' rather than 'representations, ' as both the atomic and macroscopic phenomena describe phenomena visible to chemists. In a way, an equation of chemistry is filled with hints as to what is going on at the atomic level, as a replacement for the ready ability to search after oneself. Years of study in chemistry make it possible to transform from symbolic to atomic or macroscopic views **(Daubenmire, 2014, 2).**

Types of Representation in Chemistry

Representations can be classified as internal or external. Zhang (1997) defined internal representations as “knowledge and structure” stored in memory, whereas external representations are “knowledge and structure” existing in various forms of communication in the environments. External representations can be further classified as sentential or diagrammatic representations. Sentential representations like the propositions in a text are sequential. Diagrammatic representations, in contrast, contain the information with spatial relations, like the components of a diagram. **(Shen, 2015, 4)**

The real representation is given to the student and others in the form of painting, images, hands-on materials, text, and concrete models. In student's mind, the mental representation is created **(Baptista, Martins, Conceição & Reis, 2019, 760).**

When studying a concept, the use of two or more representations is known as learning with multiple representations (MR). MR has a fundamental role to play in understanding concepts and their relationships, which implies the growth of the cognitive systems of the students, and as an area of education study this has become more important Point. It clarifies the ability of expert chemist to combine features across and within various representations to clarify their research and negotiate their shared understanding based on underlying processes and entities. "At the same time, novices have difficulty connecting representations, often resorting to the search for algorithmic approaches to symbol manipulation. Therefore it is worth looking at how to use multiple representations to render sense **(Daubemmire, 2014, 13) (Baptista, Martins, Conceição & Reis, 2019, 760, 761).**

Multiple references of Chemistry education are omnipresent. Students have to establish connections between them to benefit from multiple representations. Connecting however is a challenging task for learners. Prior work indicates that promoting connection-making improves math and science learning for students. Much of the prior work has concentrated on promoting one form of connection-making process: making sense of relations between representations conceptually. Nevertheless, recent research suggests that a second type of connection-making process plays a role in learning among students: perceptual fluidity in translating between representations **(Rau, 2015, 654).**

It can be noted that the multiple representation is important as a reference for the development of teaching materials, since the characteristics of chemical concepts require external representation through various modes, among others: modes of descriptive representation (graphs, verbal, tables), experimental, mathematical, figurative (pictorial, analogical and metaphorical), and visual representation **(Farida, Helsy, Fitriani, & Ramdhani, 2017, 1)**.

Multiple Representation (MR) Functions

Understanding concepts and connections across them, as well as processes and terms contain using multiple representation in Chemistry. In reality, depending on the information they provide and the prior experience of the students, Multiple representation can be used differently and can lead to the creation of cognitive structures of the students. In this context, it may be useful in Chemistry to use a structure to examine how learners utilize multiple representation in their learning process, i.e., to understand concepts and their relationships **(Baptista, Martins, Conceição & Reis, 2019, 762).**

Ainsworth (2006) presented a framework on the use of MR in multimedia contexts that is DeFT (Designs, Functions, Tasks). This frame introduced three basic tenets for how multiple representations function in learning. The first one is multiple representations support learning because they allow complementary processes or information to be presented. The second is a representation that is shown in a manner that restricts interpretation of another. The third tent is it can support the construction of understanding if learners are able to abstract relevant features from representations to differentiate between shared features of a domain and properties of individual representations. In addition, Daubemmire (2014) and Baptista, Martins, Conceição & Reis (2019) indicate that MR has three roles: constructing deeper understanding, encouraging interpretations and complementary roles,. The complementary role of MR is providing additional information aspects of a concept to enhance learning. Another function of this MR role is to take advantage of the representation process by using two representational processes, such as manipulating laboratory materials to explore a chemical reaction and observational photographs of students. Thus, the effectiveness of multiple representations can be observed. **(Daubemmire, 2014, 13) (Baptista, Martins, Conceição & Reis, 2019, 762).**

Single representations can include strengths and weaknesses, but the processes may complement each other and make up for these limitations by combining representations. Even though they explain the same concept and contain equivalent details, different representations can help the learner in different ways by comparing variation describing with an equation and a graph, as an example. Even though they represent the same thing and contain similar details, the graph succeeds in explaining the variance more clearly and specifically than the equation does. Similarly, a table is useful in specifically defining common values. Consequently, a mixture of process representations, e.g. a graph, an equation, and a table, may be effective in understanding a situation as each of the respective representations illustrates various aspects of the situation. The details obtained from each individual representation can therefore be combined to provide a rich overall image **(Netzell, 2014, 7).**

So that **complementary representations** support different processes for the following reasons: when presented with various representations, learners can choose to work with their preferred one; when working on different tasks, learners can select the best representation that fit the tasks; various forms of representation allow learners to use more than one approach to tackle the issue. MERs can also be used to provide complementary information when representations express completely different or some shared information. **(Shen, 2015, 9, 10)**

Since students are unique individuals who learn in various ways, they will benefit from interacting with different representations in a cognitive and intellectual way, because they have the ability to select the representation they prefer and can supplement one another by working with multiple representations. Dividing knowledge between two representations has been shown to be successful, as it helps the pupils to concentrate on various sections of the issue **(Netzell, 2014, 7, 8)**.

One representation can guide and explain another one. For example, a more familiar representation can encourage learners to understand the less familiar one; the ambiguity of the texts may be **constrained interpretations** by a diagram which contains more specific and concrete spatial information **(Shen, 2015, 9, 10).**

It can be said that enhancing interpretations provides learners with more representations to promote and endorse their interpretation of more demanding performances. Representations are deemed more available when the students are more familiar with the details or the representing process. For example, combined with molecular kits, a video with everyday life information that is important to students' eyes will allow the visualization of chemistry phenomena at different levels of understanding **(Baptista, Martins, Conceição & Reis, 2019, 762).**

Finally, MERs allow learners to “see” complex ideas and **generate deeper understanding** because MERs can be used to promote abstraction, support extension, and teach relations among representations. Abstraction is the process when learners construct references across MERs and generate more abstract concepts. Extension is to extend the understanding of a familiar representation to a new situation with other representations. Relation involves having learners translate across unfamiliar representations and make inferences among them **(Shen, 2015, Baptista, Martins, Conceição & Reis, 2019, 762).**

Ainsworth suggested that multiple representations creates an outstanding understanding of a task or phenomenon by: Netzell (2014, 7, 8)

- Enhancing abstract
- Promoting extension
- Clarifying relationships among representations

Ainsworth referred to earlier research which showed that interpreting multiple representations helps students to develop a more abstract understanding of a task. learners are able to construct a new and more abstract representation thanks to the exploration of relations between two different representations. Multiple-representation learning may also help information implementation in another scenario. Students learn how to interpret and translate between the performances by explaining the relationships between various representations. Translation between representations is one of the main goals when working with models and representations in the science classroom **(Netzell, 2014, 8)**

Seufert (2003) reveals that learners must build meaning from the corresponding characteristics of representations. This theory of the creation of coherence involves linking both within and between representations, leading learners to create a coherent image. Of course his would require them to have adequate background knowledge, to be able to work with multiple representations and to recognize when two representations introduced a conceptual conflict. By focusing on the aspects of comparing representations, both "within" and "between, " it would be possible to see where the conflict originated **(Daubemmire, 2014, 13)**

Multiple Representation Study

Netzell (2014) investigated the role of various visual models of representations in science classroom, interpret different external representations of the atom, mental models students create, and how representations can be used and built for practical learning and teaching of atomic and atomic concepts. By using systematic analysis of papers in literature the findings showed that students still found atomic structure concepts complicated and confusing. Therefore models are essential to explain atomic concepts to teachers. Analysis of the articles involved revealed three types of representations utilized to represent atomic phenomena: two-dimensional static diagrams or pictures (for example. a picture of the atom), simulations or three-dimensional videos (for example. virtual reality simulations), and visual analogies (for example. The atomic planetary Bohr model). The usage of interactive learning environments and simulations seem to have a positive impact on learning of the students.

Another study, Sunyono, Yuanita, & Ibrahim (2015) examined the effectiveness of a multi-representation-based learning model within the concept of atomic structure (known as SiMaYang) The subjects were hundred and eight students. study group was composed of the same number of graduates. the learning was carried out using multiple representations In the experimental class, whereas conventional learning was undertaken by the control classes. Results showed (1) Multiple-representation learning is more effective in building mental models for students Compared to traditional learning, in recognizing the principle of atomic structure; (2) multi-representation learning is ideal for classes where learners have a low level of ability to keep up with those with a medium and high level of ability. The results showed that lessons is involving macro-sub-micro-symbolic phenomena with multiple representations.

Rau (2015) investigated that integrating support for both perceptual fluency in connection making and conceptual sense of connections leads to higher learning gains in general chemistry among (N = 158) undergraduate students. Using an insightful atomic structure and bonding tutoring method for the chemistry. Results suggested that the integration of perceptual fluency-building support for connection making and conceptual sense-making support was effective for low-priority students, whereas high-priority students most benefited from receiving perceptual fluency-building support alone. The results indicated that learning in chemistry among students can be improved if instruction offers support for link making between multiple representations in a way that adapts to their individual learning needs.

Moreover, Sunyono, Efkar, & Munifatullah (2017) developed mental models of Student with multiple representations through model-based learning. The samples in this study were taken from a high school student in Lampung Province using random cluster sampling with the research subjects. The number of samples selected as many as two grade 10 student classes and as 76 students participating in this study. The students' mental models were evaluated by research in the form of an essay, a test of imaginative problem solving to look at the creativity potential of the student. The results showed that (1) after studying, using strategy of multiple representations, Student mental models capacity is higher, located at the intermediate-3 level; (2) Multiple representation strategies give a strong influence to the idea of atomic structure in the development of the student mental models.

Farida, Helsy, Fitriani, & Ramdhani (2017) created teaching materials about the chemical solution's material properties. Research phases were performed as follows: 1) a preliminary review in the form of content and background analysis and mapping; 2) packaging of goods for teaching materials; 3) evaluation and testing to assess the viability of the product. The teaching materials were built on the basis of the results of Herron 's principle analysis, standard textbook analysis as well as analysis of the content representation of the solution referring to Gtizkia as a colligative form. Based on the test, the product of the teaching material was found to have a characteristic in which the three levels of chemical representation on the material were related Collegiate design of the solution, using various representation modes in the form of text, image, film and animation. Macroscopic representations of experimental phenomena and procedures presentation, submicroscopic representations are visualized using inserts of text, images and video / animation that relate them to symbolic representations. The findings of the validation and feasibility review showed that the teaching materials product was appropriate and feasible for use as a secondary school learning aid.

Tima, & Sutrisno (2018) classified the level of complexity of various forms of chemical representation for learners and to investigate the impact of two separate models of teaching and learning chemistry (problem-solving based on multiple representations and problem-solving) on the cognitive achievement of the students in chemical equilibrium. The study used a quasi-experimental research. The study was performed in a senior high school in two distinct 11th grade classes. Divided into two groups: an experiment group (multiple representation model problem-solving) (N=26) and a control group (problem-solving model) (N=24); The finding showed that there is a significant difference between the two groups in mean cognitive learning scores of the students in chemical equilibrium, and the score of cognitive achievement of the students in the experiment group was better than that of the control group.

Rantih, Mulyani, & Widhiyanti (2019) analyzed the topic of intermolecular forces (IMFs) in terms of three chemical representations such as: macroscopic, submicroscopic, and symbolic representation. Descriptive approach used for paper analyzes including five general chemistry textbooks. All chemical representations provided in those Chemistry textbooks are committed to providing detailed explanations of the IMF principle. This type of study was essential to correctly formulate a concept that can avoid raising misconceptions among students.

Allred & Bretz (2019) investigated the definitions of various atomic representations by the undergraduate students. The instruments were semi-structured interviews which were conducted with first-year university chemistry students (n = 26) and second-year physical chemistry students (n = 8) after they had been taught and tested in their respective courses on the quantum model of the atom. During the interview, students were asked to interpret four atomic (the Bohr model, a boundary surface representation, a probability representation, and an electron cloud model,) and order each one from most preferred to the least preferred representations Students used ideas of classical mechanics to explain the configuration of the electron cloud, and used probabilistic terminology to characterize the atom's Bohr configuration.

Moreover, Upahi, & Ramnarain (2019) studied how chemical processes are portrayed or depicted in textbooks regarding chemistry in secondary school. A rubric developed by Gkitzia et al., Development and implementation of appropriate criteria for evaluating chemical representations in school textbooks, was adopted through analyzing the textbooks for representation types; Chemical representations relevant to text; and the appropriateness of captions. The finding revealed the dominance of symbolic representations, followed by submicroscopic representations, then hybrid and multiple. There was no evidence of mixed characterization in all three textbooks. Although most of the chemical representations related entirely to the texts, some were unlinked. The Germanicity of suitable captions in textbooks is in the clear, brief and succinct description given to a whole representation by the captions. Although our findings showed that more than half of the performances had acceptable captions, there was evidence of representations that were problematic and lacked captions.

Chemistry Understanding and Its Level

Knowing chemistry is very important, and learning from other sciences is a foundation for that. Several researchers have argued that chemistry not only explains everyday life and visible phenomena, but also describes complex and unseen principles behind chemistry-related phenomena to delineate the cause for or mechanism. Many students struggle to learn chemistry and have several misconceptions about chemistry. For example, liquid properties are taught at visible and invisible levels, and at middle and high school and college levels as abstract scientific phenomena. **(Srisawasdi and Punjabur, 2019, 153)**

Expert chemists use the strength and sophistication of chemical symbols to grasp what is happening at the atomic level, and to manipulate molecules and atoms to affect a macroscopic level visible change. Unfortunately, initial chemistry is frequently taught in a way that stresses memorizing the abstract representations of equations and reactions without a great deal of practical opportunity Connect observable macroscopic phenomena with an atomic-level understanding of the chemistry. Thus, in most chemistry classrooms, manner of chemistry instruction should address the relationship that connects macroscopic observations, symbolic representations, and views of atomic scales. If symbolic representations are presented as the goal of instruction and not as the means to gain understanding, then students will be impaired in developing a coherent understanding of chemical principles **(Daubenmire, P. L., 2014, 1). (Abir & Dori, 2013, 38).**

Chemistry curriculum in universities and high schools and aimed at delivering meaningful concepts of understanding and questioning. In addition, chemistry problems based on equations have been solved in chemistry classes much of the time, and teachers don't give much attention to the analytical understanding of the students. Therefore the load should be reduced in the chemistry curriculum and the conceptual understanding of chemistry should be emphasized **(Aydin, Aydemir, Boz, Cetin- Dinar, & Bektas, 2009, 351).**

Learners must internalize the topic through three key dimensions, namely the symbols, microscopic, and macroscopic, in order to understand chemistry. The macroscopic dimension is any chemical processes in the laboratory, such as material properties which can be detected, physical reaction changes, and measurement of changes in a substance's temperature using a thermometer. Next, microscopic level involves the abstract concepts, principles, and theories, and requires explanations based on macroscopic level observations such as molecular movement during the reaction process. Finally, the symbols include formulas and mathematical calculations to connect microscopic and macroscopic comprehension **(Ibrahim, Surif, Abduallah, Ali & selamat, 2014, 177)**.

Chemical comprehension of students can be measured by their comprehension of and transition between the four levels, which include the levels of macro, micro, symbol and process. Researchers had initially argued that chemistry is taught and understood at three levels: microscopic, also referred to as sub-microscopic – the particulate nature of the level of matter; macroscopic – the sensory level; And the symbolic one, also known as the level of representation. Dori and Hameiri (2003) added the fourth, process level of understanding of chemistry, which represents the dynamic nature of chemical reactions and the relationship between the macroscopic, microscopic and symbolic levels. **(Avargil, 2019, 285)**. **(Abir & Dori, 2013, 38)**

Jensen (1998) suggested a model that he defined as "the logical structure of Chemistry." This model applies to chemists and teachers as they interpret the logical organization of Chemistry, while it may be translated into their teaching by teachers, it does not explicitly refer to students' Metacognitive tool to monitor their understanding of the concepts and processes in chemistry. Jensen's model had three stages in it: molar, molecular and electric. The molar level in Jensen 's model had a similar significance to the macroscopic level, and we refer to the molecular level as the microscopic level **(Dangur, Avargil, Peskinb, & Dori, 2014, 299)**.

Researchers have argued that understanding symbolic and microscopic representations is particularly difficult for students because these representations are abstract and invisible, while the thinking of students relies primarily on sensory data. Still, meaningful learning can be enhanced by visualization, including drawing, computerized visualization, animation, and physical models. Visualizations help strengthen the capacity of the students to use and pass through the stages of comprehension of chemistry. **(Dangur, Avargil, Peskinb, & Dori, 2014, 299)**.

In addition to these three levels, Dori and Hameiri (2003) suggested a fourth level, the process level at which substances undergo change: they can be produced or decomposed, or they can react with other substances. Chemistry learning difficulties are primarily due to its abstract, non-observable, particulate basis and the need for agile transition through the various levels of understanding of chemistry. (**Barak & Dori, 2004, 121)** Taber (2001b) and Van Hoeve- Brouwer, (1996) suggested the addition of the quantum stage. A fifth degree of understanding of quantic chemistry has been suggested to add. **(Dangur, Avargil, Peskinb, & Dori, 2014, 299)** So that we can abstract that there are levels of understanding chemistry as:

A) **Symbol Level**: This includes graphs, equations, and formulae, The macroscopic level encompassing the tangible/ observable phenomena.
B) **Microscopic Level**: in that the learner will provide explanations at the stage of the particles. The term submicroscopic was used by [Gabel and Bunce (1994) and Treagust et al. (2003). The term microscopic has been referred to as it is possible to imagine molecules and atoms using different types of microscopes using the latest technical advances]
C) **Process Level**: that deals with the way in which substances react. The complexity of the method can be clarified on one or more of the first three stages.

Studies dealt with developing chemistry understanding:

Chin (1997) aimed at investigating the relationship between learning approaches among students and their conceptual understanding of certain chemistry concepts, describing the qualitative differences between surface and deep learning approaches to learning sciences, and identifying the types of cognitive and metacognitive strategies (related to deep learning approaches) used by students. The participants were (N=102) eighth grade students. The instrument was a Chemistry Questionnaire. Results indicated that there was no relation between the learning methods of the students and their conceptual change.

Barak & Dori (2004) investigated the combination of PBL project-based learning in an IT environment in three chemistry undergraduate courses. The subjects were 215 students at Technion's department of chemistry, Israel Institute of Technology. The instruments were a pretest, a posttest, and a final examination. The results revealed that the building of computerized models and Web-based survey activities helped to promote the ability of students to traverse mentally The four stages of understanding of chemistry: abstract, macroscopic, microscopic, and phase.

In their study, Dori, & Sasson (2008) investigated graphing skills and chemical understanding among high school students via bidirectional visual and textual representations in the case-based computerized laboratory (CCL) learning environment. The subjects of study were 3-year study consisted of (N=857) chemistry students from a variety of high schools in Israel. They were divided into an experimental group and control one. The instruments were case-based questionnaires. Results showed that learners in the CCL learning environment significantly improved their chemical understanding–retention and graphing skills in the post- with respect to the pre questionnaires.

Aydin, Aydemir, Boz, Cetin- Dinar, & Bektas (2009) evaluated whether a chemistry laboratory course called ‘‘Laboratory Experiments in Science Education’’ based on constructivist instruction accompanied with concept mapping improved pre-service chemistry teachers’ conceptual understanding of chemistry. The participants were five pre-service chemistry teachers. The instruments were semi-structured interviews and concept test. findings included that pre-service teachers had some alternative conceptions about chemistry topics. Moreover, using constructivist instruction accompanied with concept maps as an instructional tool was effective to enhance conceptual understanding of chemistry.

Caliș (2010) clarified the eighth grade students’ understanding level of some the chemistry topics in Turkish Science and Technology program. The subjects were (N=193) elementary school students of 8th grade in Bursa. The instrument was a 30-question multiple choice test. Results showed that while and physical and chemical changes, states of matter, and electron configuration, understanding level was at the good level, salts, bases and acids, structure of the matter, mixtures, and classification of matter was at the moderate level.

Morever, Şimşek, & Kabapinar (2010) investigated the effects of Inquiry-Based Learning (IBL) environments, on students' scientific process skills, attitudes towards science, and conceptual understanding of matter, The participants were twenty students from 5th grade science class in a private elementary school in Istanbul. The instruments were attitude scale, scientific process skills test and concept test. The results revealed that IBL had a positive impact on students' scientific process skills and conceptual understanding but did not make any difference on their attitudes towards science.

Talib, Shariman, & Idris (2010) described a formative assessment learning object that functioned as a resource for students to learn independently. The participants were science students at University Putra Malaysia. They were divided into two groups - The control group evaluated their knowledge and understanding of organic chemistry reactions using the prototype CAA learning object that provided only (correct or incorrect) outcome feedback. Conversely, with the help of scaffolded feedback, the experimental group evaluated their understanding of organic chemistry reactions (brief written explanation). The results revealed positive outcomes for increasing students' understanding due to the significant improvement of students' performance after they had used the computer aided assessment learning objects.

Chanin (2012) investigated Whether CHEM-PHYS 102 students have enhanced their understanding of physical and chemical change by experiencing an activity in which they interact with macroscopic and particulate-level visualizations of physical and chemical changes. The study analyzed the visualization treatment, physical and chemical change activity (PCAct). The result revealed that students still struggled with particulate explanations for chemical and physical change. Students showed an overwhelming propensity to discuss at the macroscopic level about changes in mater. in addition, students distinguished between a chemical and physical change are increasingly lacking a deeper understanding of the particle level with visual images and describe the concept.

Obenland (2012) provided new insight on effective teaching practices in chemistry classrooms and laboratories through the framework of constructivism. The instruments were multiple-choice test of conceptual knowledge in general chemistry, surveys and interviews. The results revealed that the implementation of the instructional strategies is successful within an existing exemplary chemistry classroom. Morever, Abir & Dori (2013) examined the effect of the case-based computerized laboratory (CCL) module in bilingual setting (Arabic and Hebrew) on developing higher order thinking skills among high school Arab students. The participants were 270 12th grade honors chemistry students from thirteen high schools. The instruments were unseen a narrative, real-life case study in pre and post questionnaires. The results revealed that the range of the chemistry understanding levels varied. Student scored zero when he/she posed a question, which was not chemistry-oriented. Also, there was an increase in the percentage of students who posed questions related to the process level as. In addition, the exposure to second language (SL) via gradual translation of scientific learning materials is effective in promoting students` inquiry skills.

In their study, **(Demircioğlu & Yadigaroğlu, 2014)** investigated the understanding levels of high school students, chemistry student teachers and prospective science teachers on the gas concepts. The subjects were 107 chemistry student teachers, 141 prospective science teachers and 40 high school students. The instrument was a test. The results revealed that there were significant differences between the means of high school students, the means of chemistry student teachers and prospective science teachers in favor of the high school students and student teachers have alternative conceptions that were similar to those of the high school students.

Avci, Acar Şeşen, & Kirbaşlar (2014) examined the 7th grade students' understanding of some chemistry concepts. The participants were (N=217) seventh grade students. The instrument was concept test related to the concepts of measurable properties of substance, heat and temperature, pure substance and mixture, particulate nature of substance, elements and compounds, elements and symbols, and structure of atom. The results revealed that students had misconceptions such as atoms can be seen under microscope, different elements consist of the same atoms, there is no space between particles in atoms, atoms only include nucleus. It was also found that students confused mixture and element, compound and molecule, melting and solubility and they could not distinguish the substance that include molecules.

Brandriet (2014) explored the gap between students' symbolic oxidation-reduction understandings and particulate electrochemistry understandings by investigating students' understandings of multiple representations of oxidation-reduction reactions using sequential exploratory mixed-methods study. He used six major misconceptions themes; charges & bonding, the particulate and dynamic reaction process, the role of the spectator ion, electron transfer processes, surface features of the chemical representations, and oxidation numbers. The results confirmed that the ROXCI can be used as a formative assessment of students' understandings about oxidation-reduction misconceptions.

Dangur, Avargil, Peskinb, & Dori (2014) investigated the difficulties students face when studying quantum chemistry and the potential of visualization combined with understanding chemistry at different levels to improve conceptual understanding and the effect of the visual-conceptual approach in the new module on high school honors chemistry and undergraduate students' understanding of quantum mechanical concept. The subjects were 65 volunteer and 122 honors undergraduate chemistry students. The instruments were questionnaires.

The results augmented the current set of the four chemistry understanding levels macro, micro, symbol and process by adding the quantum mechanical level as a fifth level of chemistry understanding.

Versprille (2014) investigated the first-semester general chemistry students' understanding of the chemistry underlying climate change. The subjects were (N=24) first-semester general chemistry students from a large Midwestern research Institution. The instrument was semi-structured interview protocol based on alternative conceptions and the essential principles of climate change outlined in the U.S. Climate Change Science Program (CCSP) document which pertain to chemistry. The results showed that a Chemistry of Climate Science Diagnostic Instrument (CCSI) was developed for use in courses that teach chemistry with a rich context such as climate science. The CCSI is designed for professors who want to teach general chemistry, while also addressing core climate literacy principles.

Becker, & Cooper (2014) Examined changes of energy occurring as molecules and atoms interact form the basis for understanding the macroscopic changes of energy that follow chemical processes. The results showed that Undergraduate chemistry students may focus on intuitive interpretations of potential energy, incorrect interpretations of curriculum concepts (including the notion that potential energy represents storage energy) and heuristics rather than clear understandings of the correlations between atomic – molecular structure, electrostatic forces and electricity.

A valid and reliable two-tier diagnostic test was developed by Mutlu, & Acar-Şeşen (2015) to assess students' undergraduates' understanding of the subjects of electrochemistry, acids and bases, chemical equilibrium, chemical kinetics, and thermochemistry in the context of undergraduate general chemistry course. The sample was 68 pre-service science teachers. As shown by the finding, both tiers were generated in multiple-choice format. thermochemistry, chemical kinetics, chemical equilibrium, acids and bases, and electrochemistry in the context of the general chemistry course.

Seung, Choi, & Pestel (2016) explored the understanding of chemistry processes among university students in addition to evaluate the strength of the evidence that students use in a process-oriented chemistry laboratory course to prove their arguments regarding chemistry processes. The participants came from four classes provided during the first two semesters in which the new curriculum was implemented. The instruments were students' written laboratory reports, which included the components of evidence, reflection, and claims, to examine their understanding of the process skills needed for information as eight pre-determined categories (i.e., observation, collecting/sharing data, organizing data, synthesizing, separating substance, language and symbolism/classifying, quantitative data, and employing technology). The results revealed that a process-oriented laboratory curriculum leads to the increase of the chemistry processes understanding among university students.

Moreover, **Abd el- karim (2017)** investigated the effect of using REACT strategy (Relating- Experiencing- applying – cooperating – transferring) on developing successful intelligence ability, conceptual understanding, and level of aspiration for secondary first grade female students' negative attitude toward learning chemistry. The instruments were intelligence ability test, conceptual understanding test, level of aspiration scale and attitude toward learning chemistry scale were developed and administered to 61 female students. They were divided to empirical group (N =28) and a comparison group (N=33). The result confirmed the effect of using REACT strategy on developing successful intelligence ability, conceptual understanding, increase level of aspiration and positive attitude toward learning chemistry for secondary first grade female students.

Mutlu & Acar-Şeșen (2018) clarified the influence of traditional recipe-like and guided inquiry-based approach in addition to the virtual learning and authentic environments on chemistry concepts understanding.

The subjects were (N= 68) pre-service science teachers and arbitrarily divided into four equivalent groups: Authentic Recipe-like Laboratory, Virtual Recipe-like Laboratory, Virtual Inquiry-based Laboratory and Authentic Inquiry-based Laboratory. The instrument was a two-tier General Chemistry Concept Test. The results showed that a significant difference between group post-test scores and that difference was between Authentic Inquiry-based Laboratory and Authentic Recipe-like Laboratory, Virtual Inquiry-based Laboratory and Authentic Recipe-like Laboratory.

In addition, a study conducted by **Knierim (2018)** focused on using modeling to provide High school students seemingly struggle to grasp chemical concepts and have a disconnect between their macroscopic experiences and what is occurring on submicroscopic level. In an attempt to help student's visualize chemical phenomenon, modeling in the forms of 3-D simulations, 2-D drawings, physical models, similes and metaphors were utilized and studied during the course of two units for high school Honors Chemistry classes. Students completed pre-assessments before each unit, practiced various modeling techniques, and then took post assessments. The data indicated modeling increased students' knowledge of chemistry concepts.

Kaanklao & Suwathanpornkul (2018) designed and developed a learning process based on Posner's method with design-based research for enhancing conceptual comprehension and achievement, in addition to clarify the organic chemistry misconceptions. The subjects were (N =52) students and divided into experimental (N =25) and control (N=27) group. The instruments were conceptual comprehension test in an organic chemistry and an organic chemistry achievement test. The results showed that the organic chemistry contained nine misconceptions. The experimental group's conceptual comprehension and organic chemistry achievement scores were significantly more advanced than for the control group. Moreover, Avargil (2019) investigated improvement graphing abilities, understanding of chemistry and self-efficacy through Chemistry instruction of metacognitive and graphing stimulates. The subjects three hundred and seventy students and were divided into one control group and two experimental groups. The first experimental group educated The Taste of Chemistry learning Module, focused on food-related chemistry, emphasized encouraged using of graphing skills, understanding of chemistry, and contextual learning. The second experimental group studied the module, embedded in it with the prompts. Students learnt topics of organic chemistry and biochemistry in the comparison group, that was part of the traditional syllabus. The autoefficacy, chemical understanding, and graphing skills of the experimental students improved. The experimental students' graphing skills, chemical understanding and self-efficacy increased.

Srisawasdi, & Panjaburee (2019) Used inquiry- based active learning, a process-oriented approach to put the game into practice in chemistry course at a Thai high school. The game consisted of instruction and scaffolding. The participants were 62 11th grade science students from two classes. The instruments were a conceptual understanding of chemistry test and chemistry motivation survey. Result indicated that the learners had a greatly improved conceptual understanding of chemistry in both traditional inquiry-based learning and the game-transformed inquiry-based learning. Furthermore, the results of students in two classes of post-conceptual understanding were significantly different.

Studies which interested with representation for developing chemistry understanding

Wu, Krajcik, & Soloway (2000) studied the influence a visualizing tool, eChem, on understanding eleventh graders of chemical representations. that helped learners to simultaneously visualize multiple representations in addition to create molecular models. The subjects were (N=71) students in a high school. The pre- and post-test findings demonstrated a significant increase in the understanding of chemical representations by the students. Video recording review showed that many characteristics in eChem allowed learners interpret representations and create models. Furthermore, the results indicated that models can function as a vehicle for learners to create mental images, and that various sorts of 3D models for these students were not used interchangeably.

In their study, **Jaber, & Boujaoud (2012)** identified the challenges faced by learners in a Lebanese school that obstruct their conceptual comprehension in chemistry, and the influence of a macro-micro-symbolic teaching approach on the understanding of chemical reactions among grade 10 students. The participants were (N= 46) students. The instrument were interviews, a pretest, a posttest, a concept map task, and two post-intervention tasks. Results showed that conceptual understanding of students and relational learning of chemical reactions improved by using micro– macro -symbolic approach.

McDermott & Hand (2013) examined the effect of integrated or embedded students' multiple representations in writing-to-learn activities on chemistry learning. The analysis of quantitative data indicated that for the first teacher (n = 70 students), treatment classes significantly outperformed control classes on two different measures of writing characteristics during a first unit of study, two measures of writing for the second unit, and three categories of end of unit instruction for the second unit. For the second teacher (n = 95), treatment classes outperformed control classes on two writing characteristics and three end of unit assessment categories during the only unit of study assessed. In addition, at both sites, significant positive correlations were found between all writing characteristic measurements and end of unit assessment performance.

In their study, **Ibrahim, Surif, Abduallah, Ali & selamat (2014)** developed construction of the UM Chemistry Module for teaching the fundamental concepts of chemical bonds focused on Content Representation, in addition to Pedagogical Content Knowledge. The subjects were (N=30) students. The instruments were a series of multiple-choice questions in addition to diagnostic questions. The essay questions were concerned the chemical bonds and structure. Findings demonstrated that it was difficult for most students to differentiate covalent and ionic bonds, explain the configuration of covalent and ionic bonds, and write formulas of covalent compounds. Then, the understanding of the students regarding chemical bonds improved after the Chemistry Module,

Al-Balushi & Al-Hajri (2014) explored the effect of combining concrete models with animations on comprehension of multiple visual representations among eleventh grade students in organic chemistry. Submicroscopic animations of chemical reactions and molecules in addition to concrete models were utilized to study an organic chemistry through empirical group which was consisted twenty-eight students. While only concrete models were utilized through the control group which was consisted twenty-two students. The instrument was Organic Chemistry Visualization Test (OCVT). The results indicated that combining concrete models with animations is effective in developing students' comprehension of different visual representations in organic chemistry.

Daubemmire (2014) investigated the effect of multiple representations on conceptual understanding of chemical equilibrium through resolving conflict among university students. The subjects were (N=33). The results indicated that students can establish conceptual understanding in addition to overcome disputes among various representations of the same phenomenon by verbalizing ideas as speculation (as a verbal justification for progressing in the direction of hypotheses). consequently, symbolic representations are suggested to be viewed most effectively not as a final target, but as a viaduct for linking visible, macroscopic phenomena to what is happening at the invisible, molecular level.

Shen (2015) interested with investigating students' use and understanding multiple external representations. The group study included (N=20) undergraduate students who engaged in organic course. The instruments were two interviews which were half-constructed. The results showed that for undergraduate students, diagrammatic arrow-pushing formalism representations mean a lot, while verbal arrow-pushing formalism representations have little meaning. Relevant chemical concepts for the undergraduate student can be triggered by curved arrows that can be applied to solve organic tasks.

Lansangan, Orleans, Marie, & Camacho (2018) explored students' chemistry representational competence as an alternative measure of chemistry achievement. The experiment applied in sectarian secondary stage in Manila. The participants were (15) senior students who were selected randomly. The instruments were the assessment of students' conceptual understanding of chemistry concepts, the assessment of the students' response on the tasks was evaluated using the scoring scheme patterned from Kozma's representational competence level. The scheme utilized a five-point scale (1-5) to indicate the hierarchy of students' level of understanding using representations. A modified instrument on Students' Understanding of Models in Science (SUMS) adapted from the study conducted by Treagust, Chittleborough, and Mamiala and Grosslight . Results also showed that representational competence can approximate achievement based on the significant and positive correlation it registered with the former variable.

Derman, Koçak, & Eilks (2019) investigated components of atomic structure mental models in addition to points of view about visual representations of atomic structure models in two sub-group of (N=141) university student in Turkey. Through first sub group the emphasis has been on (N=73) sketches of atomic structure mental models by freshmen science student teachers. When asked to draw the atomic structure, the study revealed a large range of different factors within the brains of the students. Most participants liked to sketch 2D structures, thus ignoring the character of the space-filling atom. Regarding atomic structure specifics, most participants focused only the most basic components of atoms. While another sub group comprised (N=68) a wide range of students from freshman to senior level who Their favored illustrations of atoms were requested in textbooks. The assessment of the sketches of participants showed that there is a need for a more cautious teaching approach for explaining the correlation between various atomic structure models and to enable learners to consider what an acceptable and contemporaneous interpretation of atomic structure would entail.

Baptista, Martins, Conceição & Reis (2019) clarified the effect of using multiple representations on developing students' cognitive structures who studied the topics of saponification reaction through a sequence of lessons. The participants were (N=68) students from three Grade 12 classes. The instruments were a focus group interview and word association test. The findings revealed that using multiple representations produced an improvement the cognitive structures of the students, with increasing the number of words in answer and the associations between words, and its nature change of these associations.

Procedures of research:

For answering the questions of research, these procedures be followed.

- **Literature review about multi representation and chemistry understanding**
- **Select multi presentation which using in research:** The research selects multi representations based on literature and previous studies and the nature of stereochemistry topics. Where some studies such as Nezell (2014), Farida, Helsy, Fitriani, & Ramdhani (2017) and Al-Balushi & Al-Hajri (2014) showed that representations had three types for representing chemical phenomenon : visual analogies, simulations or three - dimensional video (e.g virtual reality simulations) and two dimensional static diagrams or picture. Allred & Bretz (2019) interested with atom representations such as a boundary surface representation, a probability representation, an electron cloud model. Moreover, Shen (2015) used the arrow – pushing formalism.

The research used variety of computerized and mobile application based multi representation.

Multi representation involved:

Chem Tube 3D

Chem tube contains interactive 3D chemistry animation and structures, with supporting information, for studying some of the most important topics in advanced school and university chemistry and education more awesome

Virtual chemistry 3D

Vitural chemistry 3D has website involved

Mol view:

Molview is an intuitive, open – source, web – application to make chemistry and eduction more awesome. Which allow to draw Molecular structure and transform it from 2D into 3D.

Pub chem:

Pub chem is an open chemical database that collects data on chemical structures, identifiers, chemical properties, physical properties and biological activities.

Sterochem VR Application

Chirality2 application

King Draw Chemical application

Select some of important chemistry topics which can help in practicing chemistry understanding level. in this research, unit chemistry built in stereochemistry domain, whereas involve many of concepts which need to visual representation to understanding them. in the topics of stereochemistry, we can use multiple representations simultaneously to understanding some concepts such as, rotate and examine molecules from various corners, understand the features of organic molecules for instance, molecular spatial organization of atoms, bond angle, chirality, connectivity, and stereochemistry. So, some topics in stereochemistry is introduced in this unit, which allow student using multi representation to visual understanding of chemistry through deal with 3D representation about molecules and Implement process which involving. Unit contented seven topics as shown in this table:

Table (1)

Topics	Title
First	Isomerism
Second	Conformational Isomerism
Third	Structural Isomerism
Fourth	Stero Isomerism Geometric isomerism
Fifth	optical Isomerism
Sixth	Diastereomers
Seventh	Meso compounds

- Preparing the student book in "stereochemistry" unit which contained seven topics, each topic contented some tasks in which students practiced Multi representation by using variety of computerized and mobile application based multi representation. Then the student's book was presented to the arbitrators for modifications and finalization, and after carrying out modifications, student's book was presented in final version.
- Preparing The lecturer's guide in "stereochemistry" unit which illustrating How can we teach topics by using variety of computerized and mobile application based multi representation. The lecturer's guide involved how can implement computerized and mobile application based multi representation such as Chem Tube 3D, Virtual chemistry 3D, Mol view, Pubchem, Sterochem VR Application, Chirality2 application, and King Draw Chemical application. Then The lecturer's guide was presented to the arbitrators for modifications and finalization, and after carrying out modifications, the lecturer's guide was presented in final version.
- Preparing chemistry understanding test which consisted from twenty-three tasks. The chemistry understating test was presented to the arbitrators for modifications and finalization such as.

Chemistry understanding test:

Chemistry understanding test aimed to measure students' understanding at four level of chemistry understanding (Symbolic – Macro – Micro – Process). Test consisted of 22 tasks which contented Multi choice items and open – ended questions. As shown in table (2):

Table (2)

Understanding level	Task
Symbolic	4 / 7 /8 / 22
Macro	10 / 11 / 12 / 13 / 18
Micro	1/ 2/3/5/6/9/12/14/15/21
Process	1/ 3/ 9/12/16/17/19/ 20

- **The pilot study of the test:** The pilot study procedure on 34 students at 4th year in chemistry department in education college, Benha university for calculating validity and reliability test.
- **Calculate validity test:** Validity test was calculated by using formative validity (Pearson correlation coefficient between degree of task and total degree of test) as shown in table (3):

Table (3) pearson correlation coefficient between degree of task and total degree of test

Item	Correlation	Item	Correlation	Task	Correlation	Task	Correlation
1	0.45*	**7**	0.42*	**13**	0.76**	**19**	0.53**
2	0.59**	**8**	0.62**	**14**	0.42*	**20**	0.51**
3	0.67**	**9**	0.66**	**15**	0.62**	**21**	0.56**
4	0.62**	**10**	0.39*	**16**	0.65**	**22**	0.47**
5	0.59**	**11**	0.62**	**17**	0.62**		
6	0.67**	**12**	0.69*	**18**	0.60**		

Pearson correlation coefficient values ranges between (0.39: 0.76). all values are significant at the 0.05 or 0.01 level which indicates the validity of the chemistry understanding test

- **Calculate reliability test:** Reliability test was calculated by Cronbach's Alpha which equal 0.81. so that Cronbach's Alpha indicates the reliability test.

- Select study group from 4th year chemistry students at education college of benha university. The study group is one group design consisting of 87 students was selected Randomly from total (N=132) based on their desires.
- The chemistry understanding pre – test and Semi structured interviews applied on study group
- Study group learned stereochemistry unit by using multi representation
- The chemistry understating post – test and Semi structured interviews applied on study group

Results of research and its interpretation:

To ensure the validity of the research hypotheses, the current research uses the statistical T test.

The first research hypothesis:

To ensure the validity of the first hypothesis "- **there is no statistically significant difference between the means of the sample in the pretest and posttest of chemistry understanding test.", T-value is calculated as shown in Table (4):**

Table (4)

Chemistry understanding level		N	Mean	Std. Deviation	T	Df	Sig	η^2
Total degree	Pre	87	3.53	1.910	75.79	86	0.000	0.99
	Post		60.79	6.519				

- It is clear from the previous table that the value of t is significant at the significance level 0.01, which means rejecting the first zero hypothesis and the result indicates : **There is statistically significant difference between the means of the sample in the pretest and posttest of chemistry understanding test in favor of post administration.**
- This result agrees with some studies such as: (Wu, Krajcik, & Soloway, 2000), (Jaber, & Boujaoud, 2012), (McDermott & Hand,

2013), (Al-Balushi & Al-Hajri, 2014), (Ibrahim, Surif, Abduallah, Ali & selamat, 2014), (Daubemmire, 2014)

- **Eta value was high which means that the effect size was great (0.99), as a result.** this indicates the effectiveness using multiple representation on developing chemistry understanding

The second research hypothesis:

To ensure the validity of the second hypothesis :**There is no statistically significant difference between the means of the sample in the pretest and posttest of chemistry understanding test levels (symbolic – Macro – Micro – process)., T- value is calculated as shown in Table (5):**

Table (5)

Chemistry understanding level		N	Mean	Std. Deviation	T	df	Sig
Symbolic	Pre	87	0.36	0.549	61.49	86	0.000
	Post		6.71	0.806			
Macro	Pre	87	0.53	0.713	58.20		0.000
	Post		9.49	1.168			
Sub Micro	Pre	87	2.46	1.319	56.54		0.000
	Post		37.36	5.417			
Process	Pre	87	2.37	1.163	68.1		0.000
	Post		32.37	3.858			
Total degree	Pre	87	3.53	1.910	75.79		0.000
	Post		60.79	6.519			

- It is clear from the previous table that the value of t is significant at the significance level 0.01, whih means rejecting the first zero hypothesis and the result indicates : "**There is statistically significant difference between the means of the sample in the pretest and posttest of chemistry understanding test levels (symbolic – Macro – Micro – process).", in favor of post-administration."**
- Eta value was high which means that the effect size was great (0.97-0.98), as a result. this indicates the effectiveness using multiple representation on developing chemistry understanding levels.

Interpretation the result:

- The use of representation atomic structure by two-dimensional representation and three-dimensional representation is effective in students' learning chemistry especially on chemistry understanding level. Whereas using multiple representation in atomic phenomenon involve macro, - sub micro, symbolic, and process phenomena and this is consistent with studies such as (Netzell, 2014), (Sunyono, Yuanita, & Ibrahim, 2015), (Rau, 2015), (sunyono, Efkar, & Munifatullah, 2017),
- The use of multiple representation is proportional to nature of the chemistry in undergraduate university levels and this is consistent with studies such as (Rau, 2015, 654), (Allred & Bretz, 2019).
- The Use of multiple representation helps provide visual information. (Netzell, 2014),
- The Use of multiple representation helps transformation abstract concepts into sensory information.
- The Use of multiple representation helps developing chemistry understanding levels and this is consistent with studies such as (Wu, Krajcik, & Soloway, 2000), (Dori, & Sasson, 2008), (Jaber, & Boujaoud, 2012), (McDermott & Hand, 2013), (Daubemmire, 2014).

The qualitive analysis:

The qualitive analysis in this research consisted of: result of semi- structured interviews and analysis of open- ended question responses as shown:

Semi – structured interviews:

Through semi-structured interviews, it is clear that:

- Using multiple representation helps students in studying molecular structure and stereochemistry. and this is consistent with studies such as (Al-Balushi & Al-Hajri, 2014)

- When students transformed structural formula from 2D into 3D helping them understanding molecular structure. and this is consistent with studies such as (Netzell, 2014)
- Using some visual representation helped them differentiate between chiral and achiral atom. and this is consistent with studies such as (Al-Balushi & Al-Hajri, 2014)
- Using application helped them understanding some concepts such as how isomerism possesses mirror image.
- Using multiple representation helps students in imagine some stereochemistry related concepts. and this is consistent with studies such as (Al-Balushi & Al-Hajri, 2014)

Open- ended question responses:

Through analysis of responses students, **it is clear that**:

- In pre- application chemistry understanding test:
  - students cannot answer most question and in case they choose the correct answer in multi choice question, they can't interpret the reason for choose this answer.
  - At symbolic level, few of students were presented correct structured formula.
  - There was absence of understanding in macro, micro and process level.
- In post- application chemistry understanding test:
  - students can answer most question and in case they choose the correct answer in multi choice question, they can interpret the reason for choose this answer.
  - There was significant improvement at symbolic level, most students were presented correct structured formula. And provide many of structural formula for many of isomerism
  - There was significant improvement at macroscopic, micro and process level. Where most students provide correct answer and provide correct representation to isomerism

- There was significant improvement at process level, where students were able to imagine molecular structure and able to event the molecular rotation to specify the isomerism type.

Recommendations and proposals:

- Investigating the effect of using multiple representation in chemistry for developing understanding among students at secondary school.
- Investigating the effect of using multiple representation in chemistry for developing understanding among students at secondary school.
- Using multiple representation for treatment misconception in chemistry

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