Visual learning style-based chemistry mental model representation through transformative online learning

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Abstract. Analysis of learning styles is one of the main things teachers need to do before carrying out teaching. The study of learning styles can provide an overview of how a teacher designs a learning concept by students' learning styles. The learning process will show students' mental models with their respective learning styles so that these mental models become the primary material for how teachers develop students' cognitive. This research aimed to describe students' mental models in terms of students' visual learning styles. The method used is descriptive with qualitative and quantitative approaches with transformative-based learning concepts. The research results show that chemistry education students for chemistry learning innovation courses only have visual learning styles of 71.43% and audio by 28.55% and do not have kinaesthetic learning styles. This research focuses on visual learning styles to see students' mental models. The conclusion is that students still need cognitive strengthening, especially the ability to interpret phenomena at the sub microscopic level. With the visual learning style, students are expected to transform their cognitive so that they have mental structures and models relevant in theory and terminology.

1. Introduction
A mental model is a person's cognitive reflection on an idea or idea of a particular phenomenon [1]. In the context of learning chemistry, each student has initial knowledge called "preconceptions" that students will explain and show something based on basic reasoning and the results of student observations [2]. However, the preconceptions of these students need to be changed into "scientific concepts", meaning that each student needs to undergo a cognitive transformation so that students can understand a phenomenon in a concrete way [3,4]. Especially for prospective teachers, mental models are crucial because they are related to the teacher paradigm in delivering material [1]. Research [1] implements the TripleChem learning model in the ministry of students on organic chemistry in the context of mental models. Research results show that students experienced a significant increase from 1.36% to 62.73% [1]. Other research shows that improving students' mental models can be achieved by using the concept of representation [5]. It is in line with [6] that
the idea of representation is a basic science of how to understand chemistry as a whole so that students do not experience misconceptions.

According to [7], students' mental models are dynamic, so teachers have to analyze students' character. In addition, the research results by [8] that students tend to construct their mental models in a non-scientific manner so that students' ideas are not in harmony and are not scientifically relevant to concepts. This condition is referred to as preconceptions by [2] where students will still maintain their perspective on a phenomenon so that this needs to be changed into a scientific concept. In addition, [3] added that students use everyday language to explain their knowledge and description of an event. In contrast, students need to use scientific terminology to understand the context of a phenomenon easily. However, students still have difficulty constructing their knowledge, which impacts growing mental models [9]. Learning needs analysis is one strategy to determine their understanding and progress, such as learning style analysis [10,11].

Each student has different learning styles, such as visual, audio, and kinesthetic [12]. Then [12] added that learning styles significantly affect managing the information obtained, including learning outcomes. If learning styles affect learning outcomes and students' mindsets [12], then the formation of mental models is influenced by how learning styles are owned [13]. Giving problems to students based on their learning styles makes it very easy for students to understand the context of the subject matter and construct their knowledge to reduce misconceptions that occur gradually [3,13]. That is, it is highly recommended that teachers analyze learning style assessments of students so that teachers know the abilities of students and how to improve students' understanding to become more scientific [2,9,14].

Visual learning style is essential in interpreting a phenomenon [13,15]. Visual learning style is a person's ability to explain something by looking at and paying attention to image media [13]. Cognitively, visual learning styles experience the ease of understanding when students are presented with something with pictures [13]. Visual learning style is certainly in line with the concept of chemical representation at the submicroscopic level; the submicroscopic and symbolic levels are the essential parts in understanding chemical matter [6,16,17]. According to [17], students have difficulty explaining what happens in chemical reactions at the particulate (submicroscopic) level. Then, using a medium such as a magnetic ball media (physically an image or a molecular engineering model) makes it easier for students to construct their understanding in learning [17]. Cognitive transformation is undoubtedly needed so that students experience changes in preconceptions into scientific concepts so that students do not experience misconceptions and form scientific mental structures and models [3,6,9,17–19].

Transformative learning is an alternative way of changing students' cognition to be more scientific. The concept of transformative learning is considered the best concept to use, especially in higher education [20]. The role of transformative learning is very influential in changing students' perspectives and how students describe a problem [21]. Transformative learning will broaden students' horizons in learning, and they can see solutions from various perspectives so that students grow into mature learners [3,4,22,23]. On the other hand, Covid-19 is a substantial case affecting all countries globally and affecting all sectors such as the economy, politics, industry, and education. Especially in the field of education, it is necessary to have innovations in learning so that the quality of learning and teaching is needed.

During the pandemic, virtual or online learning is considered an appropriate solution where students continue to carry out the learning process and interact with teachers through various platforms [24,25]. Communication and sharing of multiple things through online learning are considered digital learning concept that brings many benefits [26]. Other studies also suggest computer-based learning with e-learning integration where teachers and students use platform technologies such as Edmodo, Social Media, Blogs, Coursera, Youtube, etc. [25]. The use of this technology is constructive for students in online activities with easy and affordable accessibility. This technology is highly recommended for students who find it difficult to obtain references, especially during the current pandemic [25].

In connection with the explanation above, learning needs to transform from face-to-face concepts in the classroom to virtual areas so that the learning process continues during the pandemic without leaving the
essence and context of the knowledge being learned [27–29]. The concept of online transformative learning is an innovative solution in constructing students' knowledge. In addition, participants will be cognitively facilitated because, before learning, the teacher analyzes students learning styles so that the learning process, interaction, and the concept of the assignment are oriented to the suitability of students' learning styles. The idea of this research will facilitate the interaction pattern between the teacher and the participants even though it is done online. Psychological experts [30] say that in schools, the student environment is referred to as a microsystem where a classroom is a place for interaction between teachers and students. This interaction significantly affects the internals of students, including the development of mental models based on their learning styles [3,31–33]. Based on the explanation, this research aims to analyze the mental models of participants (students) who have a visual learning style through transformative learning.

2. Method

![Figure 1. Cresswell's analysis spiral [34]](image)

The method used is descriptive with qualitative and quantitative approaches [34]. The sample used in chemistry education students, FKIP ULM, with chemistry learning innovation courses. Qualitatively, the data obtained are data from student analysis results from assignments and student interviews. Quantitatively, the data were obtained from the analysis of learning styles conducted before the learning process occurred. Transformative learning is a learning model used, especially in the current pandemic era. One of the sample
The indicators used is students who have experienced and have felt the impact of the pandemic situation being discussed. The sampling technique used is Intense case sampling. According to [34], "intense case sampling occurs when the researcher selects people who have had an intense experience or intense feeling related to the topic of interest". The process of analyzing research results uses the concept of study validity by Cresswells' spiral analysis, which then explains the topics brought into the research [34].

3. Discussion
The primary orientation of this research is to find out how the representation of students' mental models is based on students' learning styles. Learning style analysis is an initial analysis that is carried out before starting the teaching process by distributing a learning style questionnaire instrument. This learning style analysis is included in learning assessment, where teachers are highly recommended to determine students' learning needs so that it is easy for teachers to design a teaching and learning process. After that, the teacher makes teaching materials by adopting the concept of transformative learning and problem-based materials. The teaching materials presented consist of theoretical explanations, summaries of materials and things that are not yet understood, and problems based on representation. Then, the learning process is carried out online with a transformative learning model due to the ongoing pandemic situation. The sample used was students of Chemistry Education, Faculty of Teacher Training and Education, Lambung Mangkurat University, considering they were part of those affected by the pandemic. The following is a sketch of the transformational learning carried out.

A preliminary review of the research data results shows that chemistry education students only have a visual learning style of 71.43% and an audio learning style of 28.55%. That is, kinesthetic learning styles are not owned by them (students). The implementation of this learning style results is then integrated into the material, the brainstorming process during learning, summarizing the material and things that are difficult to understand, and the process of working on the task. The understanding carried out is adjusted to their learning style so that when they do something, they carry it out optimally. Research shows that teaching based on learning style analysis dramatically affects the quality of the teaching process carried out [32]. In addition, the use of technology is not the only strategy in improving students' cognitive abilities in learning, but how the learning presentation provided includes the process of solving problems [32]. Assessment of learning styles is part of the cognitive, affective, and even psychological aspects because each student has a unique mental model pattern and differs from one and another [2,3,9,32]. If the learning presentation
includes assignments according to their learning style, participants will be too early in understanding and interpreting the phenomenon under study [2,9,13,32].

Figure 3. Visualization of Carbon atoms with other atoms [35]

Explanation of the material. *In the earth's crust, the element carbon is a minor component. However, carbon compounds (i.e., magnesium and calcium carbonates), form common minerals (e.g., magnesite, dolomite, marble, or limestone). The corals and shells of oysters and clams are calcium carbonate. Carbon is widely distributed as coal and in the organic compounds that make up petroleum, natural gas, and plant and animal tissues. The raw sequence of chemical reactions called the carbon cycle involves converting carbon dioxide in the atmosphere to carbohydrates through photosynthesis in plants. The consumption of these carbohydrates by animals, oxidation through metabolism to produce carbon dioxide and other products, and the return of carbon dioxide to the atmosphere are among the most important biological processes [35].*

The presentation of the material is taken from [35], but this material is only as supplementary material. That is, students need to train their reasoning power and critical thinking in solving a given problem. The following are questions and visualization of students' mental models, which are the basis for analyzing their understanding.

Figure 3 shows the visualization of the C molecule with other atoms. Write and explain scientifically why the bond angles of the three molecules are different and draw orbitals to strengthen your scientific perspective?. Figure 4 shows how the students' mental models of the cases presented. According to the analysis process, it is found that 1) there are students who use quotes or citations on the results of their analysis even though they are encouraged to interpret the phenomenon according to their perspective. The second finding is that the orbital images presented are standard images that can be traced through websites and various technological media. The orbital designation in question is quite representative. Still, in this context, they are directed to be completely honest in developing their ideas so that they have the potential to build their analysis results in any visual form, not having to quote directly and in whole from websites, etc. The third reason is the answer given is related explicitly to the "molecular bond angle," where the student's response is less concrete in explanation. Although students use scientific terminology in their descriptions, they are considered less than optimal in executing the issues given. In representation, visual learning styles have adequate sketching abilities, so that their reasoning power should be explored through their analysis. However, this will take time as optimization of spatial capabilities is difficult due to weaknesses in interpreting the particulate level [2,9]. On average, students have the same tendency in interpreting their explanations, where when online learning through zoom meetings, their participation increases considerably from each session. However, when they are given time to explain their opinion directly, they are pretty passive. Then, on weekly assignments, every time students start the resume process and work on the problems presented, they tend to explain based on references and various works of
literature. Even though they can define from their perspective so that it can be seen how their mental model is with the given study, this is in line with the idea [2]. Those students tend to stick with their opinions and the observations they experience, so this becomes difficult when they are cognitively transformed. This finding is in line with research [32] that students with a “visual” learning style manage information based on what they observe and direct observation. This experience can strengthen them in defending their point of view. They need to understand the concept of representation in a concrete way so that the results of their observations (visual learning styles) are scientific. In addition, cognitive transformation can make students observe a phenomenon and interpret the acquired knowledge themselves [3,6,32].

Figure 4. Description of Student Mental Model for visual learning style

Figure 5. Visualization of the C atom: interpreting the stability of the carbon atom in various forms [36]
Figure 3 shows the visualization of the C molecule with other atoms. Write and explain scientifically why the bond angles of the three molecules are different and draw orbitals to strengthen your scientific perspective?. Figure 4 shows how Figure 5 is a presentation of the issues given to students for analysis related to the carbon atom with the question: which is more stable \( \text{C}^{4-} \) vs \( \text{C}^{4+} \) and \( \text{C} \) vs \( \text{C}^{4+} \) ?. This presentation is a submicroscopic visualization of the C atom in which students are invited to interpret how their mental model of the carbine structure is shown in Figure 5. The following describes the student's mental model for the questions related to Figure 5 given.

- Between \( \text{C}^{4-} \) vs \( \text{C}^{4+} \), the more stable is \( \text{C}^{4+} \), because the C atom requires 4 electrons to achieve a stable octet. In addition, \( \text{C}^{4-} \) also has a complete electron configuration, namely by attracting four free electrons into the outer shell so that it is durable;
- Between \( \text{C} \) vs \( \text{C}^{4+} \), the more stable is \( \text{C}^{4+} \), because the \( \text{C}^{4+} \) atom has an electron configuration that follows the duplet rule of 2, \( \text{C}^{4+} \) loses 4 electrons, and their structure becomes 2, so it is stable;
- Non-metal elements tend to form anions rather than cations, so \( \text{C}^{4-} \) is more durable than \( \text{C}^{4+} \);
- The \( \text{C}^{4-} \) is more stable than \( \text{C}^{4+} \), because to achieve stability of C (carbon) atoms by adding 4 electrons to complete the octet rule;
- The \( \text{C} \) is more stable than \( \text{C}^{4+} \) because the C atom requires a lot of energy to give or lose 4 electrons to become \( \text{C}^{4+} \).

The mental model is shown (linked to Figure 5) shows that students understand enough in theory and terminology how to interpret carbon atoms in various forms. The basic concept of stability has been fulfilled cognitively as they have understood that the C atom requires 4 electrons to achieve octet stability, the \( \text{C}^{4+} \) atom has an electron configuration that follows the duplet rule of 2, and the C atom requires a lot of energy to be given or lose 4 electrons to become \( \text{C}^{4+} \). Although the description of the mental model of students is relatively weak in Figure 4, in Figure 5 they are quite mastered in theory and terminology. The trigger factor for the formation of this mental model is that they are given time to work on the problems given and look for a variety of literature to strengthen their perspective in explaining. However, students still need to train their reasoning power and transform cognitively in interpreting particulates to explain in-depth and concretely. In this context, [17] suggest using tools or media to stimulate their reasoning so that they are easy to understand chemical molecules in submicroscopic and symbolic level.

Overall, online transformative learning based on learning styles is the right solution in developing students' mental structures and models. Analysis of learning styles is an important thing to do at the beginning of learning so that teachers know the level of understanding of students before learning. In addition, assignments and problems based on their learning style make it easier for students to develop cognitively. The presentations given by adopting the concept of correct representation of chemistry train their reasoning power so that they train them in understanding a phenomenon. Although, achieving submicroscopic understanding is still considered difficult for students, but with gradual treatment by considering learning styles such as visuals, integration of representative chemistry concepts, transformative learning concepts, and other components, it certainly makes it easier for them (students) to interpret so that they do not experience misconceptions.

4. Conclusion
Visual learning style is the main point that needs to be analyzed by the teacher. This is related to the analysis of learning needs where this analysis (learning style) makes it easier for teachers to provide learning in the classroom. The results of the research show that chemistry education students for chemistry learning innovation courses only have visual learning styles with % of 71.43% and audio of 28.55% and do not have kinesthetic learning styles. This research focuses on visual learning styles to see how their mental models
are. The conclusion is that students still need cognitive strengthening, especially how to interpret phenomena at the submicroscopic level. With visual learning styles, they are expected to be able to transform cognitively so that they have mental structures and models that are relevant in theory and terminology.

In relation to the student's mental model of the presented case, if the mental model is analyzed, it is found that 1) there are students who use quotes or citations on the results of their analysis even though they are encouraged to interpret the phenomenon according to their perspective. The second finding is that the orbital images presented are standard images that can be traced through websites and various technological media. The orbital designation in question is actually quite representative, but in this context they are directed to be completely honest in developing their ideas so that they have the potential to develop their analysis results in any visual form, not having to quote directly and in full from websites, etc. The third reason is the answer given specifically related to the "molecular bond angle" where the student's answer is less concrete in explanation. Although, students simply use scientific terminology in their explanations, they are considered less than optimal in executing the issues given. In representation, visual learning styles have adequate sketching abilities so that their reasoning power should be explored through their analysis. However, this will take time as optimization of spatial capabilities is difficult to achieve due to weaknesses in the interpretation of the particulate level [2,9].

On average, students have the same tendency in interpreting their explanations in which as online learning through zoom meetings their participation increases considerably from each meeting. However, when they are given time to explain their opinion directly they are quite passive. Then, on weekly assignments, every time they start the resume process and work on the problems presented, they tend to explain based on references and various literature, even though they can explain from their own perspective so that it can be seen how their mental model is with the given study. This is in line with the idea [2] that students tend to stick with their opinions and with the observations they experience so this becomes difficult when they are cognitively transformed. This finding is in line with research [32] that students with a "visual" learning style manage information based on what they observe and direct observation so that this experience is able to strengthen them in defending their point of view. In fact, they need to understand the concept of representation in a concrete way so that the results of their observations (visual learning styles) are scientific. In addition, cognitive transformation can make students not only observe a phenomenon, but they are able to interpret the acquired knowledge themselves [3,6,32].

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