Analysis of student’s mental model through representation chemistry textbooks based on augmented reality

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Abstract. The mental reconstruction model of students is essential to see the progress and difficulties of students in understanding chemical material, especially at the level of macroscopic, submicroscopic, and symbolic representations. This study aims 1) to see how the influence of Augmented Reality (AR) based learning media with the concept of representation, 2) to see the validity, practicality and effectiveness of the development of augmented reality-based representational chemistry textbooks, and 3) to analyze the mental models of students. The research method used is a literature study (literture study) with qualitative and quantitative approaches. The data collection technique used is the non-participant observation technique by reviewing and examining various research results related to AR-based learning media and the concept of chemical representation. The results of the study with the context of literature studies showed that AR-based learning media (teaching materials) with the concept of representation could increase the reasoning power and understanding of students in learning chemistry. The impact students can interpret more deeply so that their mental models can be reconstructed into scientific concepts. The conclusion that can be taken was that learning chemistry with the idea of representation through teaching materials based on Augmented Reality (AR) could be used as the primary reference in learning chemistry. Besides, the concept also changes the mindset and mental attitude of students as the generation of the Indonesian Nation, where improvements in mood and mentality from an early age have the potential to foster the readiness and resistance of students. That is, the application of this idea shows that natural science (chemistry) has a very vital role in the progress of the Nation, especially towards high-quality education according to the SDGs indicators.

1. Introduction
O * NET content model (the future of jobs Report, 2018) has published the classification of skills that are needed now and in the future, including (1) active learning and learning strategy, (2) complex problem solving, (3) critical thinking and analysis, (4) emotional intelligence, and (5) instruction, mentoring and teaching. That is, the points mentioned are a warning to the world of education, especially how to produce talented teachers, mentally strong, have personality, character, are creative, have confidence and problem-solving skills. This issue certainly touches all aspects of education, including science education.

The skills mentioned above, show that science, like chemistry, has an important role to play. In the context of learning chemistry, the understanding chemistry requires a concept of representation consisting of three levels, namely the macroscopic, particulate, and symbolic levels [1,2]. The
macroscopic level is a level that is not widely adopted by teachers even though the particulate level is the main point so that students not only know the chemical material in content however how they interpret it in chemistry [3–5]. It is reinforced by research [6] that the concept of representation, especially the particulate level (submicroscopic), strongly supports students’ understanding and reasoning in interpreting chemical content, especially in the experimental aspect. It means that the application of the concept of representation is the most effective strategy in improving students’ understanding of chemical materials so that misconceptions do not occur [6].

Research [7] explains that students experience difficulties when studying chemistry, where the process of visualizing chemical structures and processes at the particulate level is the hardest part to understand. Research by [8] explains that students’ interpretation of particulate level-based chemical materials can strengthen student knowledge and make it easier for teachers to know the extent of students’ mental models of material interpretation. Mental models can be described as a construct that cannot be observed, personal cognitive representations, mental images, mental processes, and mental/ internal representations of a person towards an idea or concept [7,9]. The mental models of students that appear are then analyzed to find out the extent of their interpretation of chemical materials so that they can think scientifically [7].

The process of reconstructing students’ knowledge scientifically if they do not adopt the concept of representation, then they have difficulty understanding chemistry both in content and in context [3]. Besides, their mindset is not trained to think critically, creatively, and analyze so that this has great potential for them to become misconceptions, do not understand, and their mental models misrepresent the material [6,10]. That is, mental model analysis of students is very vital, so it needs more intervention from teachers as part of improving their thinking patterns and understanding in learning [11–13].

Augmented Reality (AR) is the best solution in accommodating problems in chemistry learning, where AR has the potential to strengthen their content and knowledge [14]. The development of learning books with AR (Augmented Reality) technology can increase students’ interest and motivation to study chemical materials that are considered abstract, such as atomic models by experts [15]. AR technology itself is the integration of digital information with the user environment in real-time [16]. Understanding at the particulate level becomes easily understood by students through AR technology, where they can identify atomic models in a 3D and even 4D world [17]. Besides, the use of the Blender application will strengthen the technology products being developed. Blender is an open-source application that is used to create 3D modelling. With Blender, you can create a variety of characters, environments, molecules, and anything that smells of imagination [14,18]. Blender is not only for creating objects; however, this application can also be used in constructing an animation-based chemical molecule system from the designed modelling.

This technology concept is then integrated into the form of products, namely augmented reality textbooks and applications. Textbooks or teaching materials are considered as learning media, where according to [19] learning media is not just a product however the extent to which the media is useful and influences the mindset of students. Overall, the collaboration between the concept of augmented reality (AR) and Blender 3D is a form of educational technology, especially in training students’ representation level skills so that they are not disabled in interpreting chemical content. It means that this technology product is very relevant to the concept of representation expressed and could be an innovative concept in solving problems, especially in the context of chemistry learning. This product is also equipped with audio which is used to convey messages or a series of learning materials through voices or sounds recorded using a voice recorder.

This idea is also a form of support for the Government in the era of the industrial revolution 4.0 and renewal in the aspects of the quality of higher education following the indicators of Sustainable Development Goals (SDGs). The continuation of this innovative idea can train the creativity of the Nation’s children so that the Indonesian State becomes a superior and competitive country in the future. This idea has great potential to become a reference and source of science learning so that students, teachers, and even the public are aware that science (chemistry) is part of human and natural
life that must be studied to broaden horizons, so the main purpose of writing this literature study is in the form of the influence of instructional media, validity, practicality, and effectiveness of developing chemistry textbooks and analysis of students’ mental models can be achieved properly.

2. Method

The research method used is a literature study (library study) with a qualitative and quantitative approach. A literature study is a method used to collect data or sources related to the topic raised in a study. The steps taken include collecting library data, reading and taking notes, and comparing literature to be processed and producing conclusions.

The data collection technique used is the non-participant observation technique by reviewing and examining various research results related to AR-based learning media (teaching materials) with the concept of chemical representation. This observation technique aims to describe their perspective regarding what is observed. The data used are secondary data from textbooks, journals, scientific articles, literature reviews that contain the concepts studied. The data sources were taken for the last five years.

The data analysis technique used is that it starts with the material from the research results that are considered sequentially from the most relevant ones. Read the abstract from each researcher first to provide an assessment of whether the problems discussed are following what is to be solved, and note the important parts of the research. Analysis of the data is an attempt to systematically find and collect data to improve research understanding of the cases under study.

3. Research Result

Research [7] clearly shows that students experience difficulties when studying chemistry, where the process of visualizing chemical structures and processes at the particulate level is the hardest part to understand. It means that students in the chemistry learning process still experience obstacles so that this has a very significant impact, such as increasing misconceptions in the school environment and their mental models. Mental models can be described as a construct that cannot be observed, personal cognitive representations, mental images, mental processes, and mental/internal representations of a person towards an idea or concept [7,9]. The mental models of students that emerge are then analyzed to determine the extent of their interpretation of chemical materials so that they can think scientifically [7]. On the other hand, it is also explained that students’ interpretation of particulate level-based chemical materials can strengthen student knowledge and make it easier for teachers to know the extent of students’ mental models of material interpretation [8].

The fundamental orientation that should be achieved in the learning process of chemistry is that students can master the chemical concepts they learn and be able to relate to the concepts that have been studied, especially concepts in chemistry that are interrelated and very in touch with the universe[20]. The learning process becomes complicated because each concept must be mastered correctly before mastering other concepts. Chemistry lessons are often seen as boring, difficult, and abstract. This statement is relevant to the results of research [21] that 9% of students’ learning difficulties in determining topics, 9% in identifying tools and materials, 22% in preparing experimental steps, 35% in preparing project completion schedules, 39% in taking data, 4% in presenting data, 87% in choosing the type of data analysis technique, 52% doing data analysis, 13% discussing the results of data analysis, and 4% making conclusions. Student misconceptions in data analysis techniques were 74.64%, and those who did not understand the concept were 3.9%. This study concludes that the highest learning difficulties for students in project-based practicum are at the stage of selecting the type of data analysis technique because students experience misconceptions and do not understand the concept of data analysis techniques. That is, the research mentioned shows that the reconstruction of learners’ knowledge is needed. The formation of natural and scientific knowledge certainly has a major impact on their mental model so that their ability not only understands, however, can interpret [7,22,23].
“…Even up until now, the misconceptions of molecules in salt crystals are so strongly anchored that even in scientifically trained circles one is not using the correct mental model of ions or ion grids according to salt crystals. The historical development of models concerning the structure of matter and the big number of misconceptions can be read more precisely in other places….\cite{24}”.

3.1. Knowing how the influence of Augmented Reality (AR) based learning media with the concept of representation

In connection with the above, the level of students’ understanding of a concept, especially abstract concepts, can be seen from students’ mental models \cite{25}. Mental model analysis can be used to determine students’ conceptions of a given concept in the learning process, especially concepts that are abstract or very particulate (submicroscopic). The mental model that students have for teachers is very important, both for determining suitable learning strategies for future learning, teaching materials, or media that are structured so that students’ understanding of a concept becomes a complete unit \cite{26}.

The development of teaching materials is considered a very appropriate strategy to reduce misconceptions and improve mental models of students, especially in studying chemical materials. According to \cite{19} that textbooks are part of instructional media content, where learning media are not only learning products, however, the extent to which they affect and increase students’ learning passion. Learning media is a component of learning resources or physical vehicles that contain instructional material in the student environment that can stimulate students to learn. Media has a clear function, namely to clarify, facilitate and make interesting material that will be conveyed by the teacher to students so that it can motivate their learning and make the learning process efficient \cite{27}. Overall, the existence of learning media is very vital in the knowledge construction process of students so that they can easily interpret phenomena based on the concept of representation. This statement is relevant to the quotation below.

“….Function of many media. The studies on retaining of information show that the use of media is essential and advantageous. But, it has to be considered to what extent a medium can help in chemistry lessons and what difficulties have to be taken into account. The functions can be of the following kind-Motivation: media can be used to motivate the learner during the chemistry lesson if there is no primary experience from the learner’s environment available-Process of perception: figures or tables of measurements can be used, if it is not possible to run an experiment to test a hypothesis….\cite{28}”.

AR technology can also answer chemical phenomena that they have considered difficult. As in the case of a practicum, it takes a long time to prepare, and the participants dislike the practicum. By bringing virtual objects to the front of the class, it will make practicum more lively and fun. The use of AR textbooks not only increases student motivation; however, it also improves student learning outcomes. That way, students’ mental models will be more easily formed after simulations in class, thus helping students understand abstract chemical phenomena.

3.2. Knowing the validity, practicality, and effectiveness of developing representative chemistry textbooks based on Augmented Reality

AR (Augmented Reality) is a technology that integrates digital information with the user environment in real-time \cite{29} (Widodo, Setiawan and Rostianingsih, 2016). The application of AR technology is considered very helpful and makes it easier for students to understand the content, especially in chemistry learning \cite{17,30}. Besides, this technological aspect can provide new experiences and open their minds about a unique way of learning based on information communication technology (ICT) \cite{14,15}. The results of the study \cite{31} show that the integration of Augmented Reality (AR) adds value to the teaching and learning process of students. AR is considered as a technology combination system that combines objects with a real environment in a virtual manner, and its application is highly interactive \cite{32}. This AR concept is very relevant to the concept of representation described earlier, where the particulate level factor in learning chemistry is the most appropriate solution so that students can interpret content holistically \cite{17,33}. The development of AR technology makes it easier for
teachers to process a learning media so that students can easily digest it because of the interactive, communicative, and unique nature of AR media [34]. AR technology is considered very effective to be used in the learning process because students will find a different atmosphere when learning, such as visualization in 3D / 4D format [35]. That is, the concept of representation using AR technology is the right solution in chemistry learning, especially particulate and symbolic level interpretation [11,16,17,36].

3.3. Analysis of students’ mental models
Overall, the development of chemical teaching materials based on AR technology is an innovative idea considering that currently, the use of technology is very rapid. Also, Augmented Reality technology has very strong relevance to the concept of chemical representation so that the development of teaching materials based on Augmented Reality technology with the concept of representation is the right combination in accommodating problems in chemistry learning. An indicator that teaching materials as learning media are not just a product; however, it influences the mindset and mental learning of students[37]. This influence indirectly affects the mental models of students so that the learning process using teaching materials based on Augmented Reality technology with the concept of representation simplifies the process of their knowledge construction. Mental model refinement is a phase of correcting the paradigm regarding chemical materials, which many consider negative so that the issue of misconception will slowly disappear. The right and scientific mental model changes the mindset of students in responding to various phenomena in their lives, including knowing the universe that chemistry is not just a part of science. However, chemistry has a very big role for future generations. The biggest impact of improving the mental model is that the quality of education will increase and develop in the State of Indonesia, especially towards the quality of education based on the indicators of Sustainable Development Goals (SDGs).

4. Conclusion
The results of research with the context of literature studies show that AR-based learning media (teaching materials) with the concept of representation can be used as a reference in learning chemistry, especially atomic structure material, which by using this textbook has a big influence on the reasoning power and understanding of students and can find out mental models of learners. The impact, students, can interpret more deeply so that their mental models can be reconstructed into scientific concepts. Learning chemistry with the concept of representation through teaching materials based on Augmented Reality (AR) can be used as the main reference in learning chemistry, where this concept is fundamental in a concrete understanding of chemistry. Besides, this concept also has the potential to change the mindset and mentality of students as the generation of the Indonesian Nation, where improvement in thinking and mental patterns from an early age has the potential to foster the readiness and resistance of students. That is, the application of this idea shows that natural science (chemistry) has a very vital role in the progress of the Nation, especially towards high-quality education according to the SDGs indicators.

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