Original Article

Available online at
www.heca-analitika.com/jeml

Journal of Educational Management and Learning

Vol. 1, No. 1, 2023

Augmented Reality and Student Learning: Analysis of Mental Models of Salt Hydrolysis at SMAN 51 Jakarta, Indonesia

Anisa Umayah [1], Maria Paristiowati [1], Hanhan Dianhar [1] and Nur Azizah Putri Hasibuan [2,*]

[1] Chemistry Education Department, Math dan Science Faculty, Universitas Negeri Jakarta, Jl. Pemuda No. 10, Rawamangun 13220, Jakarta, Indonesia; anisaumayah1@gmail.com (A.U.); maria.paristiowati@unj.ac.id (M.P.); hanhan@unj.ac.id (H.D.)

[2] Chemistry Education Department, Education, and Teacher Training Faculty, UIN Syekh Ali Hasan Ahmad Addary Padangsidimpuan. Jl. H.T. Rizal Nurdin, KM 4.5, Padangsidimpuan City, 22733, North Sumatera. Indonesia; nurazizahhsb@uinsyahada.ac.id (N.A.P.H.)

* Correspondence: nurazizahhsb@uinsyahada.ac.id

Article History

Received 3 July 2023
Revised 2 August 2023
Accepted 13 August 2023
Available Online 18 August 2023

Keywords:
Augmented reality
Mental model
Salt hydrolysis
Submicroscopic representations
Science education

Abstract

This study aimed to ascertain students' mental models while learning about salt hydrolysis through augmented reality (AR). The study comprised 36 participants from Public High School 51 in Jakarta. A descriptive qualitative approach was adopted for this research, employing various data collection methods such as written drawings, interviews, classroom observations, teacher notes, student worksheets, and final tests. In categorizing students' mental models, three main types emerged: scientific, synthetic, and initial mental models. The findings revealed that 7.20% of students fell into the initial mental model category, 53.90% exhibited synthetic mental models, and 38.90% demonstrated scientific mental models. Notably, incorporating AR into salt hydrolysis learning predominantly influenced the development of synthetic mental models. The study's results also indicated that the utilization of AR positively enhanced students' spatial abilities in understanding submicroscopic representations.

1. Introduction

In the era of globalization, the significance of science as a cornerstone of progress cannot be overstated. Science is pivotal in propelling the advancement of both science and technology. Among the various domains of scientific study, chemistry stands out as a particularly crucial field [1].

Through the pursuit of chemistry education, students are expected to be able to connect the knowledge gained in these lessons with everyday phenomena. In studying chemistry, students must also be able to connect concepts previously learned and those just taught. If participant students do not understand one of the studied concepts, it is difficult to learn other concepts that accompany it. In addition, chemical concepts are abstract, so students need higher-order thinking skills to understand these concepts [2].

According to Johnstone, there are three levels of chemical representation. The first is the macroscopic level, which involves explaining chemical substances, changes, and reactions that can be directly observed with our senses. The second is the submicroscopic level, which describes matter in terms of its tiny particles and properties. The third is the symbolic level, where various images, symbols, and mathematical equations represent chemical concepts and relationships. Developing a comprehensive understanding of chemistry requires a solid grasp of these three representation levels [3].

However, learning chemistry in general only emphasizes macroscopic and symbolic representation when experiencing learning difficulties [4]. This can cause problems stemming from the way students' abilities in representing submicroscopic so that learning is not meaningful [5].

The understanding of the three chemical representations influences the formation of mental models. According to Coll [6], a mental model is a simple form of a concept to provide stimulus, visualization, and explanation of scientific phenomena. Mental models also describe, explain, and even predict various phenomena [7]. Experts utilize these mental models to gauge students' understanding of specific phenomena, especially to uncover their genuine thoughts and ideas [5].

In the process of learning chemistry, students frequently encounter challenges in grasping the taught material, which in turn can contribute positively to the refinement of their mental models. Prior to acquiring knowledge, students often hold incomplete notions; however, as they engage with the subject matter, their mental models transform [8]. This transformation is categorized into two distinct types: scientific and non-scientific mental models. According to Kurnaz & Ermen [9], non-scientific mental models stem from inappropriate pedagogical methods and insufficiencies in both the curriculum and learning resources. Consequently, educators must understand their student's mental models to prevent the development of non-scientific mental models. Instances of non-scientific mental models, such as synthetic and initial mental models, can lead to misconceptions among students.

One challenging area in chemistry education is the concept of salt hydrolysis, which involves a complex and sequential phenomenon where one chemical substance is interconnected with another, as seen in acid-base solutions, chemical equilibrium, and related processes [10]. For students to effectively grasp a scientific mental model, the instructor must possess a comprehensive and accurate mental model initially. Additionally, integrating educational applications can help minimize the development of non-scientific mental models [11]. Augmented reality-assisted learning, for instance, holds the potential to enhance students' mental models [12, 13]. Augmented reality (AR) denotes a technology that seamlessly merges the virtual and physical realms in real time, all generated by a computer. Objects from the virtual world are superimposed onto the real environment. This technology encompasses various forms like text, animations, 3D models, or videos, enabling users to encounter virtual objects as if they were physically present in the real world [14].

Several studies on mental models have been conducted in Indonesia [15–17]. One such study was undertaken by Supriadi [18], focusing on mental models as they pertain to comprehending various types of chemical reactions. Ridwan et al. [1] also contributed to the field with their research on the mental models associated with salt hydrolysis. This study aims to contribute further by examining how students' mental models develop while learning about salt hydrolysis in a class XI MIPA at SMAN 51 Jakarta, Indonesia, using an AR application as a learning tool.

2. Methods

2.1. Research Methodology

This study utilizes a qualitative descriptive approach, concentrating on 36 students (20 girls, 16 boys) from Jakarta's Public High School 51, Indonesia. The data collection process includes observation sheets, student worksheets, interviews, reflective journals, final tests, and writing and drawing techniques.

The data analysis procedure in this study adhered to the fundamental stages of data analysis: data reduction, data presentation, and verification, as outlined by reference [10]. The initial step, data reduction, encompassed the selection of students' responses on their mental models, which were subsequently examined in the context of salt hydrolysis learning. The data for reduction was sourced from surveys of students' mental models, their final exams, and insights gained from interviews and reflective journals. Following this, data presentation was employed to refine and systematically organize the information acquired from students' responses to the provided worksheets.

To draw well-grounded conclusions, an additional verification phase was undertaken, designed to ascertain a definitive outcome. These conclusions were drawn from the processed data of the preceding stages, namely data reduction and data presentation. The verification process was pivotal in establishing the reliability of this research's findings. In accordance with Guba and Lincoln [19], the concept of trustworthiness serves as a vital criterion in qualitative research, encompassing attributes of validity, reliability, and objectivity. Strategies such as prolonged engagement, persistent observation, progressive subjectivity and member verification were integrated to ensure the data's credibility and accuracy.

2.2. Augmented Reality

Augmented Reality (AR) is a technology that combines the virtual world with the real world in the form of computer applications. AR displays can be text, animations, 3D

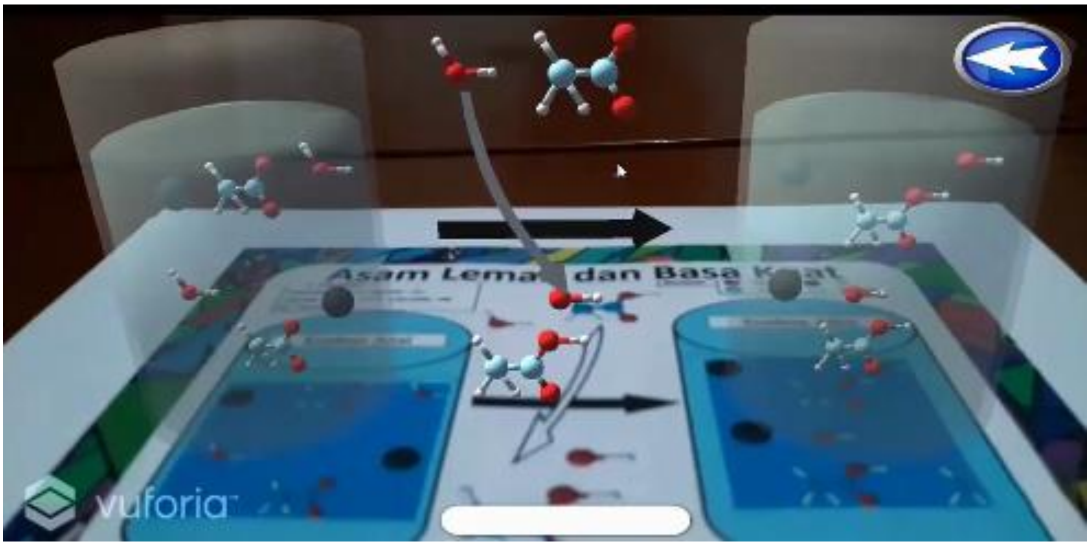

Figure 1. The augmented reality application.

Table 1. Mental model category.

Types of Mental Model	Content
Initial Models	Perceptions that are not consistent with scientific knowledge (can only represent macroscopically and symbolically, not sub-microscopically).
Synthetic Models	Perceptions that are partly or partially inconsistent with scientific knowledge (can link all three representations but still have some errors)
Scientific Models	Perceptions that following scientific answers (can connect the three representations correctly)

models, or videos presented to the user as real [10]. Creating AR requires toolkits such as Vuforia SDK, Unity 3D and 3D Blender, and Android SDK. Vuforia is a framework that has a function for developing AR applications on mobile phones. Unity 3D is a set of tools that can be used to create technology-based games such as graphics, audio, physical, and the internet. And Blender is software for creating content in applications, especially 3D or features [20]. The AR application used is an application that explains salt hydrolysis material. This AR application is called Salt Hydrolysis AR. A visual representation of the AR application can be observed in Figure 1.

2.3. Mental Model

In the exploration of mental models, one must initiate with inquiries concerning salt hydrolysis. Within this study, students were presented with five questions on the comprehension of salt hydrolysis through open-ended queries, specifically descriptions. These five questions encompass the following topics: the fundamental concept of salt hydrolysis; hydrolysis reactions of salts derived from strong acids and strong bases; hydrolysis reactions of salts derived from strong acids and weak bases; salt hydrolysis reactions derived from weak acids and strong bases, as well as salt hydrolysis reactions derived from weak acids and weak bases.

All the provided questions have undergone validation by four chemistry education lecturers from Jakarta State University. The validation process was facilitated using a validation sheet, which evaluated the appropriateness of the questions to the intended indicators and the suitability of the language employed within the questions. The scoring rubric utilized for the classification of mental models aligns with the criteria outlined in Table 1.

3. Results and Discussions

3.1. Learning using AR

In this study, three distinct learning stages were carried out, namely, the engage, explore, and explain stages, each conducted throughout four meetings. The progression of stages in this research is visually depicted in Figure 2. The initial phase is the engage stage. Students are presented with worksheets designed to elicit their mental models during this stage. This is achieved by introducing initial questions and facilitating question-and-answer sessions through PowerPoint slides. Notably, certain students exhibit a preference for the Engage stage. This inclination stems from allowing students to engage in discussions with the teacher, thus mitigating the abrupt introduction of new questions. This observation is supported by insights gleaned from students' reflective journals.

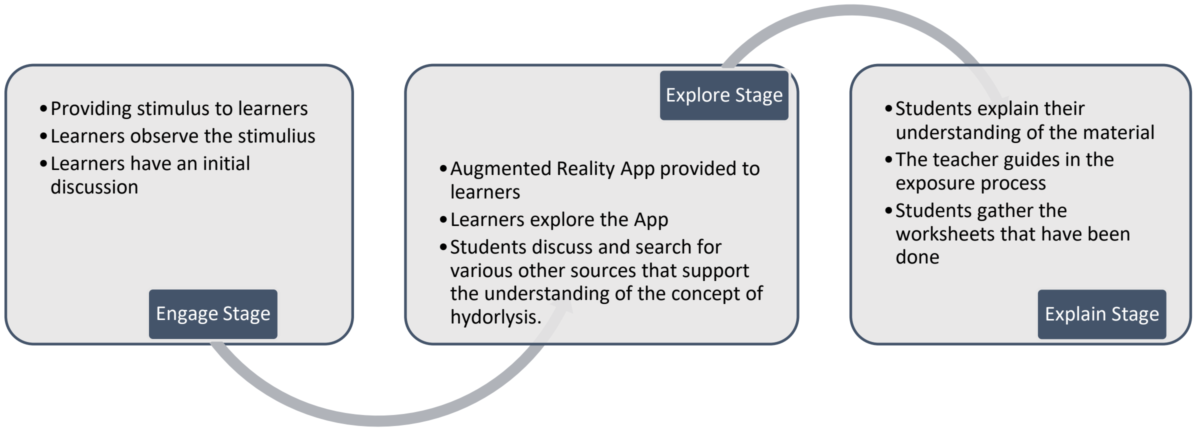

Figure 2. 3E (engage-explore-explain) learning stages.

> *"At the engage stage, I like it because I have a discussion with the teacher. There are no sudden questions." (Reflective Journal, Learners 20, February 23, 2021)*

During this stage, students also demonstrated positive responsiveness when interacting with the teacher. They effectively participated in providing explanations, answering questions, and engaging in discussions.

> *"Students are active in responding to the teacher's explanations, both in responding to the material and in asking questions related to the material." (Observer 02, Observation Sheet, March 9, 2021)*

The subsequent phase is the explore stage. During this stage, students not only rely on their existing comprehension of the salt hydrolysis reaction process but also benefit from the assistance of an Augmented Reality (AR) application. This application aids them in exploring submicroscopic depictions of the salt hydrolysis reaction process. Notably, during this stage, students exhibit high concentration and engagement in the learning process.

> *"When viewed from the answers and liveliness of students, it can be said that students are quite focused on learning" (Observer 02, Observation Sheet, February 23, 2021)*

Students display notable enthusiasm during this stage due to their utilization of AR-based applications. Students have also mentioned that this application marks their inaugural exposure to such a tool within the context of learning. These sentiments are expressed in the reflective journals of students.

> *"It's really exciting, ma'am. The application is super interesting. I've never come across anything like this before. Usually, teachers don't use things like this." (Student 08, Interview, March 9, 2021)*

The final phase is the explain stage. During this stage, students are tasked with elucidating and presenting the outcomes of their problem-solving endeavors undertaken in the prior phase. They articulate what they have gleaned throughout the learning process. At this juncture, the teacher consistently provides reinforcement to the students. Additionally, students are allowed to express their sentiments, particularly regarding the impact they've experienced while engaging with the AR application.

Upon transitioning to the explain stage, it becomes evident that the application has a significant role in augmenting understanding. Nonetheless, it is worth noting that this application necessitates a substantial memory allocation for downloading.

> *"I believe it's beneficial and enhances comprehension, ma'am. Initially, I had a misconception about molecules being liquid, but during the AR learning phase, I rectified that. However, ma'am, I encountered a constraint due to limited cellphone storage. To download the app, I had to delete some files." (Student 16, Reflective Journal, March 2, 2021*

The AR application is instrumental in learning salt hydrolysis in increasing students' understanding of connecting the three representations. This, in turn, contributes to the enhancement of students' mental models.

3.2. Mental Model of Students in Learning Salt Hydrolysis

The analysis of students' explanations yielded three distinct categories of mental models. Collectively, the distribution of these mental models among the students was as follows: an initial mental model constituted 7.20%, a synthetic mental model accounted for 53.90%, and a scientific mental model comprised 38.90%. This distribution is visually depicted in Figure 3.

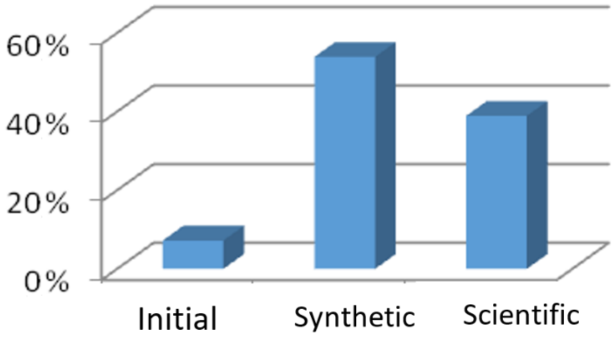

Figure 3: Histogram of mental models

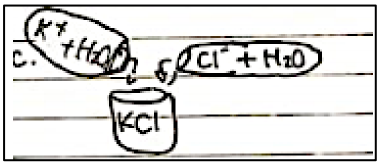

Figure 4. Depiction of the Macroscopic Representation of the Initial Mental Model.

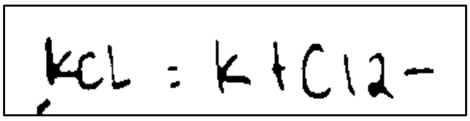

Figure 5. Depiction of the Symbolic Representation of the Initial Mental Model

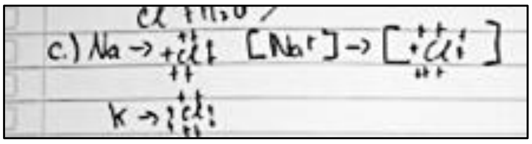

Figure 6. Submicroscopic representation of the initial mental model

3.3. Initial Model

In the initial mental model, students' comprehension is restricted solely to macroscopic representations or exclusively to symbolic representations. In some cases, students may not answer accurately, and submicroscopic representations remain imperceptible at this stage. Their initial mental model scored an average of 7.20%. For example, one student inaccurately described a KCl solution using litmus paper (Figure 4).

Figure 4 highlights a disparity between students' comprehension and scientific concepts. Though asked to describe KCl as a result of strong acid and base, some discussed K^+ and Cl^- ions reacting with water. Evolution toward symbolic representation is shown in Figure 5.

In Figure 5, students achieve symbolic representation but struggle to match the reference. Their grasp of the KCl compound solution is partial, and submicroscopic understanding remains incomplete (Figure 6).

Figure 6 demonstrates students' visualization limited to macroscopic and symbolic levels, depicting molecules as floating spheres. These misconceptions span topics like hydrolysis of salts and reactions of salts from various acids and bases. The initial mental model originates from student thinking, supported by interviews.

> *"I'm really lost when it comes to chemistry, and now there are reactions and pictures to deal with." (Student 07, Interview, April 21, 2021)*

3.4. Synthetic Models

In the synthetic mental model, students have achieved comprehension of the submicroscopic representation, yet certain misconceptions persist. While students can articulate the occurrences in the salt hydrolysis reaction process, they encounter challenges in effectively bridging the connections between different representations, particularly within the submicroscopic representations. The synthetic mental model accounts for 53.90% of the total. Among the students, the synthetic mental model encompasses the concept of salt hydrolysis. Here, students perceive salt hydrolysis as the reaction between salt and water.

> *"Salt hydrolysis is the reaction of salt with water" (Student 12, Worksheet, February 23, 2021)*

This synthetic mental model arises because, during the discussion in the exploration stage, students tend to search for these definitions on the internet. Another synthetic mental model is observed in symbolic representations, where students can jot down reactions but struggle to elucidate their written content, indicating a lack of comprehension. Students accurately convey their reactions, yet their understanding of the material remains elusive.

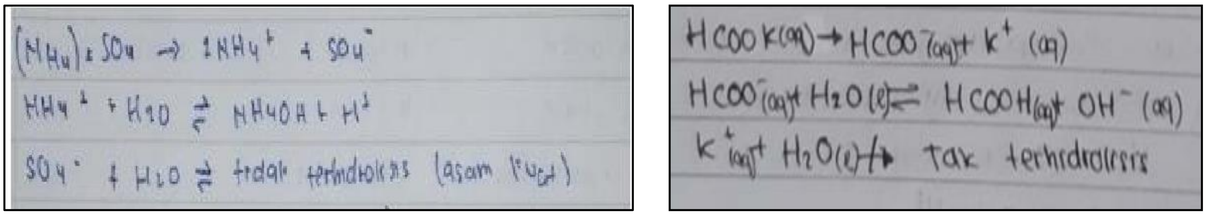

Figure 7. Writing the salt hydrolysis reaction process.

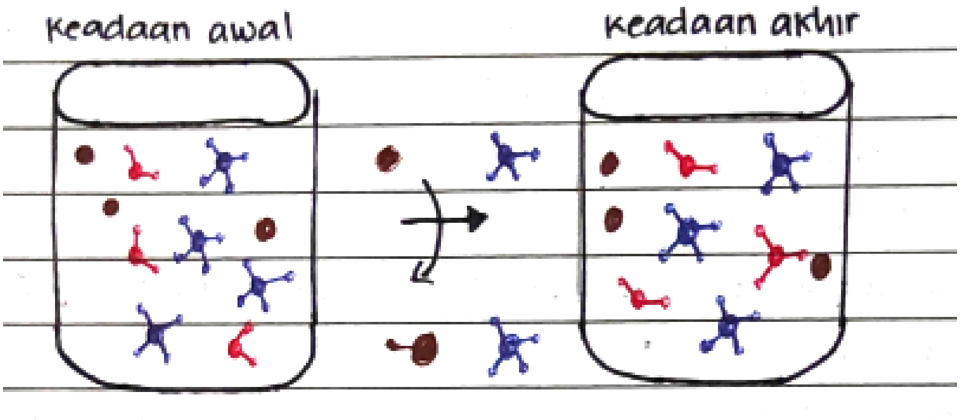

Figure 8. Submicroscopic representation of synthetic mental models.

Referring to Figure 7, the symbolic representation depicts a salt hydrolysis reaction process. Observably, the responses provided by the students indicate the presence of a synthetic mental model. Notably, the students omitted the inclusion of reaction phases in their answers, and interestingly, they also documented the salt hydrolysis reaction process in accordance with the compounds involved.

> *Considering my study materials, the salt derived from a strong acid and a weak base appears acidic due to its origin from a potent acid. Therefore, the salt is strong, indicating a robust acidic quality, ma'am. Consequently, when encountering a combination of strong and weak components, the inference is that hydrolyzation occurs exclusively with the weaker component" (Student 09, Interview, April 25, 2021)*

Synthetic mental models also manifested within submicroscopic representations. While students exhibit the capability to elucidate sub-microscopic details of molecules, misconceptions persist due to an incomplete grasp of the salt hydrolysis reaction process. This incomprehension gives rise to the development of synthetic mental models.

Figure 8 depicts a submicroscopic scenario within a synthetic mental model. This prevalent synthetic mental model stands out when compared to others. Students comprehend submicroscopic representations but struggle to differentiate the element sizes, forming this model. This mental model is also prompted by inaccuracies in describing SO42- ions. The correct depiction involves a double bond between the S atom and two O atoms, while a single bond exists with the other O, yet students frequently simplify it to forms like NH4+ or entirely omit double bonds. This confusion often stems from an incomplete understanding of hydrocarbons—alkanes, alkenes, and alkynes.

This mental model's development is influenced by the teacher's explanations and individual perceptions during learning, aligning with Dewi's findings [21]. Synthetic mental models emerge due to students' misconceptions, categorized into five factors: student conditions, teachers, teaching methods, chemistry materials, and context. Notably, the synthetic mental model is most prominent within Public High School 51 Jakarta.

3.5. Scientific Model

In the scientific mental model, students' comprehension is adept at connecting the three scientific representations. A percentage of 38.90% represents the scientific mental model. Students possess a comprehensive understanding of the concept of salt hydrolysis. Students who engage with the scientific mental models can effectively elucidate the concept of salt hydrolysis, outline the process of salt hydrolysis reactions, and accurately relate pH levels to describe submicroscopic representations. Within this model, students accurately expound upon the concept of salt hydrolysis. This assertion is corroborated by the responses provided by students on their answer sheets.

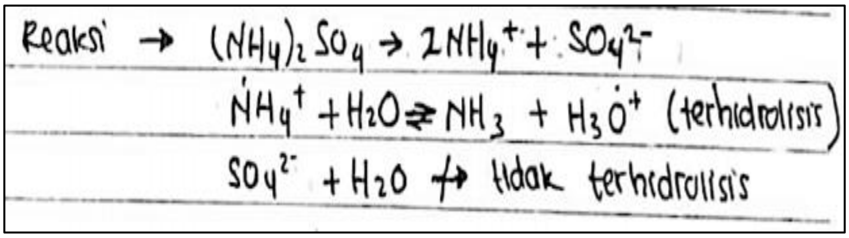

Figure 9. Depiction of the macroscopic representation of the scientific mental model

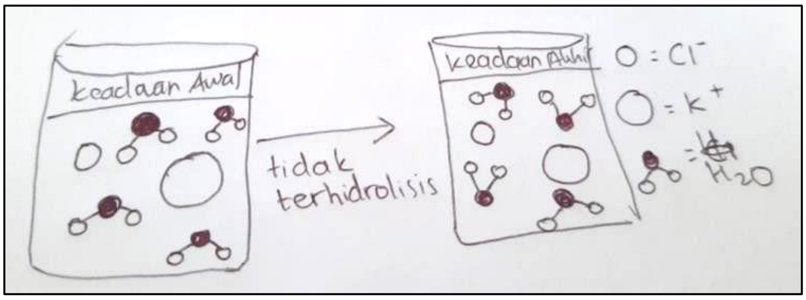

Figure 10. Writing the salt hydrolysis reaction process.

"Salt hydrolysis is a reaction between water and salt cations or anions that produce H_3O^+ and OH- ions due to the transfer of protons between ions and water" (Student 31, Interview, April 22, 2021)

Based on the student's responses regarding salt hydrolysis, it is evident that participants have grasped the concept in terms of its definition and Bronsted-Lowry acids and bases. The answers provided by the students during interviews mirrored those given when they were completing the questions. When interviewed, the information sources that students drew upon for their understanding of salt hydrolysis included a blend of explanations from the teacher, materials from school books, and online sources. The student's ability to connect the transfer of protons between ions and water can be attributed to the teacher's approach of integrating acid-base lessons with discussions on salt hydrolysis. This correlation is supported by the insights gained from student interviews.

"I provided that response because you hinted about our group's discussion on acid-base learning, Ma'am, specifically regarding the Bronsted-Lowry concept. So, I presumed that since salt hydrolysis is connected to Bronsted-Lowry, there would indeed be a transfer of protons between ions and water. Salt hydrolysis, after all, involves ions and water." (Student 31, Interview, April 22, 2021)

Macroscopic representations depicted by students in accordance with scientific concepts, as shown in Figure 9, align with scientific mental models. Students adeptly and accurately portray these macroscopic illustrations. This proficiency is a result of their practice, which contributes to enhancing their macroscopic representations. A scientific mental model is also evident in the depiction of the salt hydrolysis reaction, as illustrated in Figure 10. Students successfully portray salts derived from strong acids and weak bases, such as Ammonium Sulfate. Upon interviewing the students, it is clear that they possess a solid comprehension of the process.

"In my opinion, because the reaction of Ammonium Sulphate consists of NH_4^+ cations from weak bases and SO_4^{2-} anions from strong acids, well, both are reacted with water and later the cations of weak bases are hydrolyzed. Then it will eventually produce H_3O^+ ions and then add the ions because at first, it's still H_2O." (Student 08, Interview, April 21, 2021

Based on the findings of the interviews, it is evident that students understand the equation governing the complete salt hydrolysis reaction. They can effectively differentiate between cations originating from weak bases and anions stemming from strong acids, as well as predict the resultant products before the reaction. The outcomes of the interviews align with the concepts outlined in the work of Whitten et al. [22], which stipulates that salts derived from strong acids and weak bases exhibit acidic behavior due to hydrolysis of cations from weak bases, yielding H3O+ ions and subsequently increasing their concentration in the solution.

Furthermore, students adeptly establish scientific connections through submicroscopic representations.

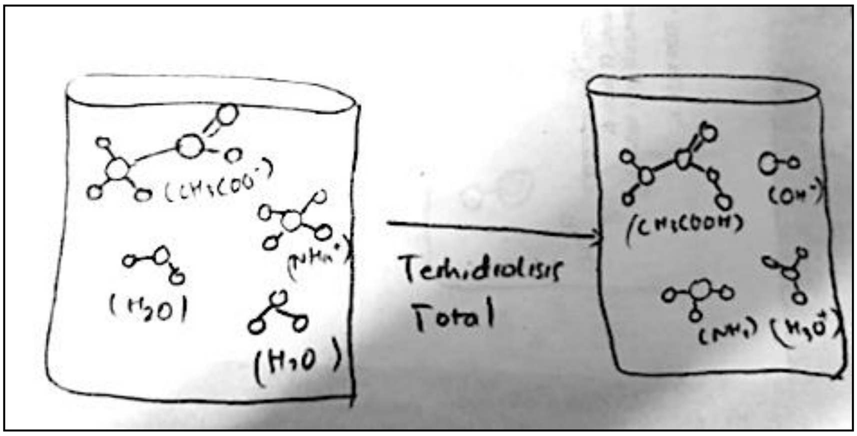

Figure 11. Depiction of a submicroscopic representation of a scientific mental model.

This proficiency is exemplified by the submicroscopic representation provided in Figure 11, which illustrates their comprehension of the submicroscopic salt hydrolysis process. Upon observing the image, students depict these compounds and ions in molecular forms and provide accompanying labels for each compound or ion. This demonstration highlights students' mastery of scientific mental models, as evidenced by their accurate and scientifically grounded responses.

Within the illustration, it becomes evident that students proactively contemplate the structure of ions that remain invisible to the naked eye. Additionally, students elaborate that Cl- and K+ ions remain inert when in contact with water molecules. The development of a scientific mental model during the study of salt hydrolysis stems from a combination of factors: the application of Augmented Reality (AR), the guidance offered by the teacher, students' creativity, and their utilization of authoritative sources such as scholarly articles, textbooks, and reputable online resources.

4. Conclusions

This study highlights that most class XI MIPA 3 students at SMAN 51 Jakarta possess synthetic mental models. These models, influenced by teacher explanations, student conditions, and learning methods, demonstrate a scientific orientation of 38.90%, a significant synthetic representation of 53.90%, and a lower initial model of 7.20%. The introduction of Augmented Reality (AR) learning media has notably increased student interest in learning chemistry due to its novelty. AR proves particularly beneficial in enhancing students' ability to conceptualize reactions and submicroscopic structures, thereby refining their mental models. This underscores the potential of AR applications in advancing education techniques. AR applications could enhance the teaching of topics like salt hydrolysis, offering flexible online and offline learning opportunities. However, the usability of AR demands clearer instructions, and further development is essential. Thus, there is a call for dynamic evolution in AR application development to ensure their continued effectiveness in education.

Author Contributions: Conceptualization, A.U. and M.P.; methodology, A.U.; software, A.U.; validation, M.P., H.D.; formal analysis, A.U.; investigation, A.U..; resources, M.P.; data curation, A.U.; writing—original draft preparation, A.U.; writing—review and editing, N.A.P.H.; visualization, N.A.P.H.; supervision, M.P. and H.D.; project administration, H.D. All authors have read and agreed to the published version of the manuscript.

Funding: This study does not receive external funding.

Ethical Clearance: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not available.

Conflicts of Interest: All the authors declare that there are no conflicts of interest.

References

1. Andina, R. E., Rahmawati, Y., Ridwan, A. (2019). Analysis of students' mental model of salt hydrolysis concepts at Klaten, Central Java, *Journal of Physics: Conference Series*, Vol. 1157, 042009. doi:10.1088/1742-6596/1157/4/042009
2. Latifah, S., Sugiharto, S., Saputro, A. N. C. (2014). Studi komparasi penggunaan praktikum dan demonstrasi pada metode problem solving terhadap prestasi belajar siswa materi hidrolisis garam kelas xi ilmu alam sma al islam 1 surakarta tahun pelajaran 2010/2011, *Jurnal Pendidikan Kimia*, Vol. 3, No. 3, 111–120
3. Treagust, D., Chittleborough, G., Mamiala, T. (2003). The role of submicroscopic and symbolic representations in chemical explanations, *International Journal of Science Education*, Vol. 25, No. 11, 1353–1368. doi:10.1080/0950069032000070306
4. Hinton, M. E., Nakhleh, M. B. (1999). Students? Microscopic, Macroscopic, and Symbolic Representations of Chemical Reactions, *The Chemical Educator*, Vol. 4, No. 5, 158–167. doi:10.1007/s00897990325a

5. Harrison, A. G., Treagust, D. F. (2000). A typology of school science models, *International Journal of Science Education*, Vol. 22, No. 9, 1011–1026. doi:10.1080/095006900416884

6. COLL, R. K., TAYLOR, N. (2002). MENTAL MODELS IN CHEMISTRY: SENIOR CHEMISTRY STUDENTS' MENTAL MODELS OF CHEMICAL BONDING, *Chem. Educ. Res. Pract.*, Vol. 3, No. 2, 175–184. doi:10.1039/B2RP90014A

7. Rouse, W. B., Morris, N. M. (1986). On looking into the black box: Prospects and limits in the search for mental models., *Psychological Bulletin*, Vol. 100, No. 3, 349–363. doi:10.1037/0033-2909.100.3.349

8. Chittleborough, G. (2004). The role of teaching models and chemical representations in developing students' mental models of chemical phenomena, Curtin University

9. Kurnaz, M. A., Emen, A. Y. (2014). Student Mental Models Related to Expansion and Contraction., *Acta Didactica Napocensia*, Vol. 7, No. 1, 59–67

10. Maratusholihah, N. F., Rahayu, S., Fajaroh, F. (2017). Analisis miskonsepsi siswa sma pada materi hidrolisis garam dan larutan penyangga, *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, Vol. 2, No. 7, 919–926

11. Idroes, G. M., Noviandy, T. R., Maulana, A., Irvanizam, I., Jalil, Z., Lensoni, L., Lala, A., Abas, A. H., Tallei, T. E., Idroes, R. (2023). Student Perspectives on the Role of Artificial Intelligence in Education: A Survey-Based Analysis, *Journal of Educational Management and Learning*, Vol. 1, No. 1, 8–15. doi:10.60084/jeml.v1i1.58

12. Supriadi, S., Wildan, W., Siahaan, J., Muntari, M., Haris, M. (2023). Pengembangan Media Pembelajaran Kimia Berbasis Teknologi Augmented Reality (AR) untuk Melatih Model Mental Siswa SMA di Daerah Geopark Rinjani, *Chemistry Education Practice*, Vol. 6, No. 1, 8–14

13. Garzón, J. (2021). An overview of twenty-five years of augmented reality in education, *Multimodal Technologies and Interaction*, Vol. 5, No. 7, 37

14. Suryawinata, B. A. (2010). Pemanfaatan augmented reality dalam memvisualisasikan produk perumahan melalui internet, *ComTech: Computer, Mathematics and Engineering Applications*, Vol. 1, No. 2, 758–769

15. Latipah, J., Jamilah, S. N., Sari, S. T. (2021). Analysis of student's mental model through representation chemistry textbooks based on augmented reality, *Journal of Physics: Conference Series* (Vol. 1760), IOP Publishing, 12050

16. Sunyono, S., Sudjarwo, S. (2018). Mental models of atomic structure concepts of 11th grade chemistry students

17. Amalia, F. R., Ibnu, S., Widarti, H. R., Wuni, H. (2018). Students' Mental Models of Acid and Base Concepts Taught Using Cognitive Apprenticeship Learning Model, *Jurnal Pendidikan IPA Indonesia*, Vol. 7, No. 2, 187–192

18. Supriadi, S., Ibnu, S., Yahmin, Y. (2018). Analisis model mental mahasiswa pendidikan kimia dalam memahami berbagai jenis reaksi kimia, *Jurnal Pijar MIPA*, Vol. 13, No. 1, 1–5

19. Guba, E. G., Lincoln, Y. S. (1989). *Fourth Generation Evaluation*, Sage

20. Diaz, C., Hincapié, M., Moreno, G. (2015). How the Type of Content in Educative Augmented Reality Application Affects the Learning Experience, *Procedia Computer Science*, Vol. 75, 205–212. doi:10.1016/j.procs.2015.12.239

21. Dewi, K. M., Suja, I. W., Sastrawidana, I. D. K. (2018). MODEL MENTAL SISWA TENTANG TERMOKIMIA, *Jurnal Pendidikan Kimia Undiksha*, Vol. 2, No. 2, 45. doi:10.23887/jjpk.v2i2.21165

22. Whitten, K. H., Davis, R. E., Peck, M. L., Stanley, G. G. (2013). Chemistry 10th, *United States of America: Cengage Learning*