UNESA Journal of Chemical Education *ISSN: 2252-9454*
Vol. 13, No.1 pp.52–59, January2024

ANALYSIS OF MULTIPLE REPRESENTATION ABILITIES OF MALE AND FEMALE GRADE STUDENT AT SMAN 1 TANJUNGANOM IN ACID-BASE MATERIAL

***Rahayu Nur Hidayah and Ivan Ashif Ardhana**

Departement of Chemistry Education FTIK UIN Sayyid Ali Rahmatullah Tulungagung

e-mail: rahayunurhidayah29@gmail.com

Abstract

The field of chemistry has become one of the abstract sciences, particularly in the context of acid-base materials, thus requiring the integration of multiple representations. Incomplete multiple representation abilities in students can lead to difficulties in understanding acid-base materials. Therefore, this research aims to analyze (1) the level of students' multiple representation abilities in acid-base materials and (2) the differences in the levels of multiple representation abilities between male and female students. The research method used is a comparative ex-post facto approach with a quantitative approach. The research instruments include test questions based on the DAC framework and interview sheets. The results of this research are as follows: (1) the average level of multiple representation abilities is 20%, categorized as very poor. The percentages of multiple representation abilities based on the DAC framework are 29% for definition, 18% for algorithmic, and 20% for conceptual. The highest percentage in the DAC framework indicators is D-R at 32%, while the lowest percentage is C-O at 11%. (2) There is a difference in the levels of multiple representation abilities between male and female students, as evidenced by the results of the Mann-Whitney U test, with an Asymp. Sig. (2-tailed) value of 0.000 ≤ 0.05.

Keywords: multiple representations, acid-base, DAC framework, gender differences.

INTRODUCTION

Chemistry is a science that contains complex concepts and phenomena that are abstract or not directly observable, making it difficult for students to understand [1]. One of these challenging topics is acid-base chemistry. Acid-base chemistry encompasses several sub-concepts, including acid-base theories, properties of acids and bases, acid-base indicators, pH calculations, degree of ionization, and the acid-base constant of a solution. The acid-base concept often leads to student difficulties and misconceptions. Several studies have addressed the challenges faced by students, including difficulties in connecting H and OH symbols with acid-base properties, distinguishing between weak and strong acids and bases, and differentiating between compounds and ion particles in acid-base reactions [2][3]. Furthermore, students may struggle to articulate acid-base theories in a symbolic manner, have trouble differentiating between ionization constants and degree of ionization, and tend to use pH values to determine the strength of acids instead of the ionization capabilities of substances [4].

The research findings presented above indicate that students find acid-base chemistry challenging. Their difficulties in comprehending acid-base topics are often rooted in their inability to connect macroscopic, submicroscopic, and symbolic representations, leading to misunderstandings. One of the difficulties students encounter in learning chemistry is their inability to link different levels of representation [5]. One approach to address students' inability to connect macroscopic, submicroscopic, and symbolic representations is to assess students' multiple representation abilities early in the chemistry learning process. Multiple representation abilities refer to the capacity to re-present a concept in various forms that depict macroscopic, submicroscopic, and symbolic representations [6]. However, in practice, students often focus on macroscopic or symbolic representations only. In connection with prior research, it was found that only 37.15% of students are unable to connect all three levels of representation [7]. The inability to connect these representations must not be ignored as it can lead to students struggling to comprehend more complex concepts and prevent misconceptions.

The difficulty students face in understanding material presented in multiple representations prevents them from constructing mental models to comprehend phenomena. Based on observations conducted at SMAN 1 Tanjunganom, teachers have not emphasized the three representations aspect in teaching acid-base materials. Additionally, there hasn't been an analysis of multiple representation abilities at SMAN 1 Tanjunganom, so teachers are not aware of the students' understanding levels in terms of their multiple representation abilities. The analysis of multiple representation abilities in acid-base materials aims to identify whether students have a comprehensive or fragmented understanding [2]. Consequently, the results of this analysis can be used by teachers as an evaluation tool to enhance chemistry learning, particularly in acid-base materials, to foster a comprehensive and unfragmented understanding.

Previous research has shown that students' multiple representation abilities vary. Factors influencing multiple representation abilities include physical condition, psychological factors, habits, and gender differences. Gender differences in thinking and problem-solving approaches result in different ways for male and female students to solve problems, leading to differences in their abilities [8]. The ability to solve problems depends on how male and female students approach problem-solving tasks, resulting in differences in their abilities to both understanding and acquiring knowledge in chemistry [9]. In previous research, it was found that females had a greater multiple representation ability at 42.5%, while males had a lower ability at 38.1%. Low interest in learning chemistry and a lack of prior exposure to multiple representations in chemistry education are factors contributing to students' inability to connect the three levels of representation [5].

One instrument used to assess multiple representation abilities is a test based on the DAC framework (Definition, Algorithmic, and Conceptual). This framework measures multiple representation abilities based on definitional, algorithmic, and conceptual levels connected to the three levels of representation. The DAC framework comprises ten indicators, making it suitable for constructing tests to assess multiple representation abilities [10]. This test makes it easier for teachers to classify students as either having or not having the ability to connect multiple representations [11]. Based on previous research, it is a suitable instrument to analyze multiple representation abilities in acid-base chemistry. With this background, this study aims to analyze the level of multiple representation abilities of male and female students in acid-base chemistry at SMA Negeri 1 Tanjunganom using open-ended test questions. Therefore, this research will assist teachers and students in evaluating the level of multiple representation abilities of male and female students.

METHOD

The research method used in this study is a comparative ex-post facto research with a quantitative approach to analyze students' multiple representation abilities in acid-base chemistry [12]. The population in this study consists of 11th-grade students at SMAN 1 Tanjunganom. The sample collection technique used is purposive sampling. Samples were selected based on teacher considerations, so the chosen samples are students who have not previously taken tests related to multiple representations, especially in acid-base chemistry. Another consideration is that the selected students have been taught the acid-base chemistry material by their teacher. The samples used include Class XI IPA 1, XI IPA 3, XI IPA 4, XI IPA 5, and XI IPA 6, totaling 139 students, consisting of 48 males and 91 females. The research instruments include 14 multiple representation questions based on the DAC framework and an interview sheet. The validity of the test instrument was confirmed by one chemistry lecturer from UIN Sayyid Ali Rahmatullah Tulungagung and one chemistry teacher from High School in Nganjuk, showing a validity rate of 93%. Empirical validity results from one class showed that 11 questions were valid (1,2,3,4,5,6,9,10,12,13,14), and 3 questions were not valid (7,8,11). The reliability of the 11 valid questions yielded a value of 0.772, indicating a high level of question reliability. The difficulty level of the questions showed that 9 questions had moderate difficulty criteria, and 5 questions had high difficulty criteria. The instrument that underwent testing and revision was then distributed to the students, and their answers were scored on their response sheets based on the answer key and scoring guidelines. The next step is to calculate the percentage of students' multiple representation abilities using the formula:

$$\%\ ability = \frac{Total\ student\ score}{Maximum\ score} \times 100\%$$

The final step is to classify students' multiple representation abilities based on the criteria categories for multiple representation abilities, as seen in Table 1, according to [13].

Table 1. Category of Multiple Representation Abilities

Score (%)	Category
81-100	Very Good
61-80	Good
41-60	Adequate
21-40	Limited
<20	Very Limited

The researcher also analyzed student score data to determine the difference in the level of multiple representation abilities between male and female students using the Mann-Whitney U test because the data is not normally distributed and not homogenous.

RESULTS AND DISCUSSION

1. Level of Students' Multiple Representation Abilities in Acid-Base Chemistry

The percentage of students' multiple representation abilities in acid-base chemistry is 20%, which falls into the "Very Limited" category. This is supported by previous research, which indicated that only 21.92% of students were able to connect all three levels of representation completely [14]. Previous research has suggested that the low ability of students to connect multiple representations in chemistry is due to a lack of training in linking one level of representation to another [15]. This aligns with the results of interviews, which showed that teachers had not previously taught chemistry learning, especially acid-base chemistry, in connection with multiple representation abilities. Additionally, teachers typically only provided theoretical or calculation-based questions, making it challenging for students to work on multiple representation questions.

The research results based on the DAC framework, as seen in Figure 1, show that the highest percentage is in the "Definition" (D) category at 29%. This means that students have a limited ability to recall, understand, apply, and recognize a definition in acid-base chemistry. The "Definition" framework covers concepts that require memorization and understanding. This is in line with the characteristic of students, which focuses more on memorization when learning acid-base chemistry, resulting in a higher definition ability compared to other abilities [16]. In question number 6, which contains the "Definition" framework, students wrote that NaOH is a strong base solution and the image representing NaOH is image C because the number of $Na+$ and OH^- ions is the same. Students have good recall abilities regarding the properties of a NaOH solution but still struggle to analyze submicroscopic images, leading to different interpretations [14]. The difficulties students face indicate that they have good memorization skills, but they have not mastered the ability to analyze a concept. Based on the interview results, students prefer to use memorization techniques in their learning, making it easy for them to solve theoretical concept-based questions but difficult to work on application-based questions.

ISSN: 2252-9454

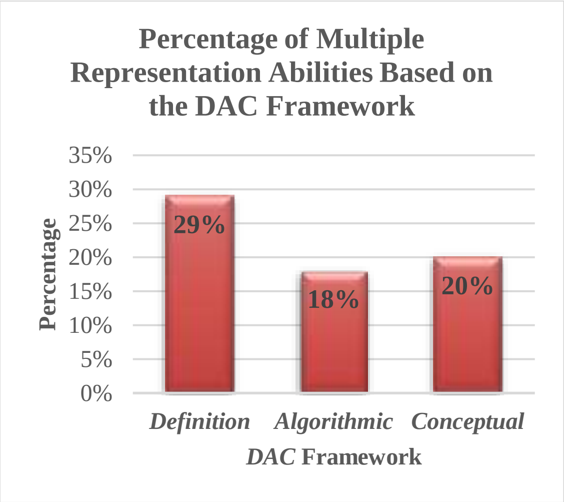


Image 1. Percentage of Average Students' Multiple Representation Abilities Based on the DAC Framework (Definition, Algorithmic, and Conceptual)

The lowest percentage in the DAC framework is in the "Algorithmic" category at 18%, meaning that students have a very limited ability to connect the three levels of representation, including converting macroscopic questions into submicroscopic ones, analyzing macroscopic questions into dimensions, converting submicroscopic representations into symbolic ones, and multi-step operations. Students tend to be unable to apply formulas effectively and have a limited grasp of mathematical operations, such as exponentiation, roots, and logarithms [17]. The results regarding the "Conceptual" framework are at 20%, indicating that students have a very limited ability to analyze a phenomenon, analyze images, analyze data in the form of tables or graphs, and predict results. In chemistry education, especially in acid-base chemistry, students are not taught at the submicroscopic level, leading to difficulties in interpreting submicroscopic representations [18].

2. Differences in the Level of Multiple Representation Abilities between Male and Female Students in Acid-Base Chemistry

The level of multiple representation abilities between male and female students exhibits a significant difference, as evidenced by a significance value of 0.000 (Asymp. Sig. 2-tailed), which is less than 0.05. Therefore, it can be concluded that there is a difference in the level of multiple representation abilities between male and female students. This statement is depicted in Image 3, with the percentage of multiple representation abilities among female students being higher at 24%, while the percentage for male students is 15%. This research aligns with previous studies, which indicated that the percentage of multiple representation abilities among female students is greater than that of male students, with females at 42.5% and males at 38.1% [7]. Females possess a higher level of creative thinking ability, reaching 57.7%, compared to 50.8% in males. On the other hand, female students exhibit self-confidence, a strong sense of curiosity, a high interest in learning, perseverance, dedication to learning, and a more positive attitude toward chemistry, in comparison to male students [19], [20]. Therefore, based on the research results, the test scores of female students are higher than those of male students, indicating that the academic achievements of females are higher in terms of cognitive aspects.

Image 2 displays the percentage of multiple representation abilities of male and female students based on the indicators of the DAC framework. In the DAC indicators, females, overall, exhibit a higher average percentage than males. This is evident in the D-RUA and D-R indicators, where male students have percentages of 21% and 24%, while female students have percentages of 30% and 36%. This suggests that the ability to remember, memorize, understand, and recognize a concept is higher among female students compared to male students. Biologically, females have a larger hippocampus than males, which results in a better long-term memory storage capability. Additionally, the brains of females and males have different structures, particularly the cerebral cortex, which controls thinking, intellectual functions, and decision-making. The female brain receives approximately 20% more blood flow and nerve connections. Consequently, females may be able to respond to and process information more rapidly than males [21]. This explains why female students excel in tasks that require memorization or recalling concepts.

ISSN: 2252-9454

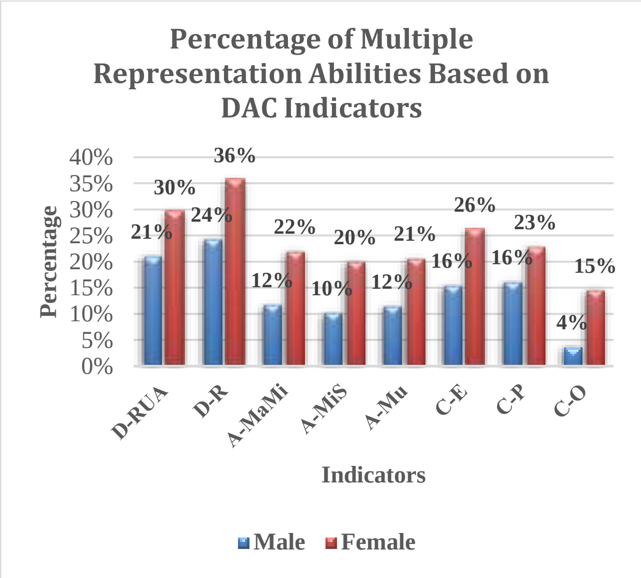


Image 2. The average percentage of multiple representation abilities based on indicators within the DAC Framework.

The percentage of students' multiple representation abilities in the A-MaMi, A-MiS, and A-Mu indicators is as follows: male students scored 12%, 10%, and 12%, while female students scored 22%, 20%, and 21%. This means that female students have higher abilities than male students in converting macroscopic levels into submicroscopic, converting macroscopic into symbolic, and analyzing chemical problems using multiple steps. Overall, female students have a stronger ability to solve mathematical problems compared to male students because females excel in planning problems solving, executing problem-solving plans, and being thorough in their double-checking [22]. On the other hand, both male and female students can handle problems at the symbolic level but may not fully grasp the concepts, often relying on memorizing variations or formulas, leading to difficulties in linking them to various concepts. An example question, such as question number 12, is shown in Image 4, and student responses are observed in Image 5 and Image 6.

Take a look at the following picture!

Based on the picture on the side, calculate the pH of the formed solution! ($Ka = 1 \times 10^{-7}$) Observe the pH graph below!

Based on the calculated pH, determine the color changes that occur according to the pH graph above! (Assume that the addition of solute does not change the volume of the solution)

Image 4. Question Number 12

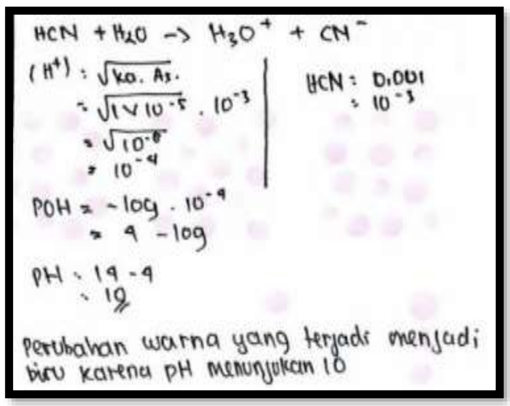


Image 5. Male Student's Response

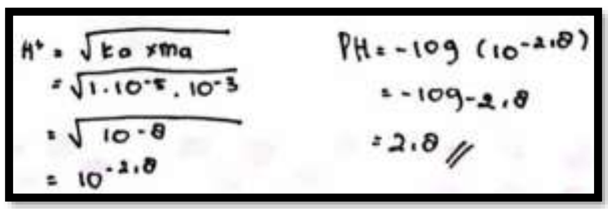
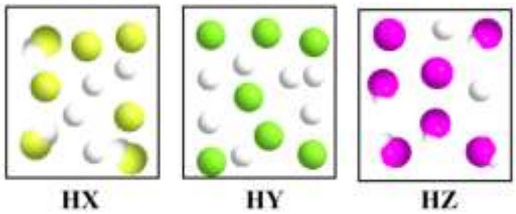


Image 6. Female Student's Response

Based on Image 5, it can be observed that male students encountered difficulties in comprehending the concept of calculating the pH of weak acids because they incorrectly used pOH to solve problems related to weak acid, whereas pOH should be used to calculate the concentration of base for pH calculations. This error can be attributed to male students being accustomed to receiving formulas to directly apply when solving problems, but they struggle to explain how these formulas are derived. In essence, male students can effectively complete calculations without fully grasping the underlying concept [2]. In Image 6, it is evident that female students made errors when calculating [H^+] and pH for weak acids, possibly due to difficulties with mathematical calculations. Therefore, female students seem to have a solid understanding of the concept of calculating the pH of weak acids but face challenges in mathematical operations such as exponentiation and logarithms. Female students excel in problem analysis and connecting concepts when compared to their male counterparts, whereas males demonstrate stronger logical skills.

The level of multiple representation abilities based on indicators C-E, C-P, and C-O indicates that male students scored 16%, 16%, and 4%, while female students scored 26%, 23%, and 15%. This means that female students exhibit better capabilities compared to males in analyzing phenomena related to acids and bases in their surroundings, analyzing submicroscopic images, and predicting outcomes. The lowest percentage was found in the C-O indicator because students made errors when solving problems or deviated from the acid-base concept, resulting in inaccuracies in predicting the final outcome. Furthermore, when working on problems containing indicators C-E, C-P, and C-O, every student should ideally possess strong conceptual analysis skills to ensure the ability to connect the macroscopic, submicroscopic, and symbolic levels. An example question from question number 8 can be observed in Image 7, and student responses are analyzed in Image 8 and Image 9.

Presented below are several submicroscopic images! In each image, water solvent is not depicted.



Description

The following is a breakdown of the reactions HX, HY, and HZ:

$HX(aq) \rightarrow H^+(aq) + X^-(aq)$

$HY(aq) \rightarrow H^+(aq) + Y^-(aq)$

$HZ(aq) \rightarrow H^+(aq) + Z^-(aq)$

If the three solutions above are tested with litmus paper, all three solutions can turn blue litmus paper red. Compare the pH of these three solutions! Provide the reasoning!

Image 7. Question Number 8.

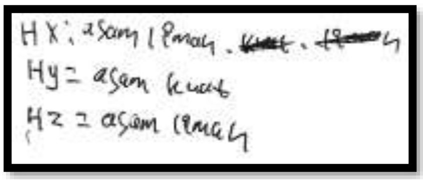


Image 8. Answer from Male Student

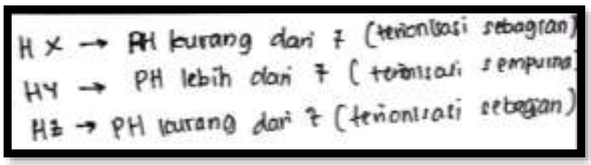


Image 9. Answer from Female Student.

Image 8 shows that male students only write down the properties of the reactions HX, HY, and HZ but are unable to explain them at the molecular level. This causes male students to have difficulty in arranging the pH of acids based on these three reactions. In Image 9, it is shown that female students can analyze images down to the molecular level but have difficulty determining the properties of the reactions HX, HY, and HZ. Therefore, female students also have difficulty predicting the order of acid pH based on these three reactions. This is because students have difficulty in analyzing submicroscopic images, causing both male and female students to have difficulty predicting their acidity levels. The submicroscopic level is rarely taught in chemistry learning, especially in acid-base material, so students make interpretations according to their understanding. Difficulty in analyzing the submicroscopic level also causes students to have difficulty in developing their conceptual understanding [3].

CONCLUSION

Based on the research analysis of the multiple representation abilities in acid-base material using the DAC framework instrument, it can be concluded that (1) the average level of multiple representation abilities is 20%, categorized as very poor. The percentages of multiple representation abilities based on the DAC framework are 29% for definition, 18% for algorithmic, and 20% for conceptual. The highest percentage in the DAC framework indicators is D-R at 32%, while the lowest percentage is C-O at 11%. (2) There is a difference in the levels of multiple representation abilities between male and female students, as evidenced by the results of the Mann-Whitney U test, with an Asymp. Sig. (2-tailed) value of $0.000 \leq 0.05$.

REFERENCES

1. Alighiri, D. Drastisianti, A., and Susilaningsih, E. 2018. Pemahaman Konsep Siswa Materi Larutan Penyangga Dalam Pembelajaran Multiple Representasi. *Jurnal Inovasi Pendidikan Kimia*, Vol 12, No 2, pp. 2192–2200.

2. Ardhana, I. A. 2020. Dampak Process-Oriented Guided-Inquiry Learning (POGIL) terhadap Pengetahuan Metakognitif Siswa pada Topik Asam-Basa. *Hydrogen:Jurnal Kependidikan Kimia*, Vol 8, No 1, pp. 1–10.

3. Parniyanda, F. and Sukarmin. 2022. Pengembangan Software Anti MISCHEMistry dengan Menggunakan Strategi Conceptual Change Text Untuk Mereduksi Miskonsepsi Siswa pada Materi Asam Basa. *UNESA Journal of Chemical Education*, Vol 11, No 2, pp. 87–94.

[4] Utami, I., Mulyani, B., and Yamtinah, S. 2020. Identifikasi Miskonsepsi Asam-basa dengan Two Tier Multiple Choice Dilengkapi Interview. *Jurnal Pendidikan Kimia*, Vol 9, No 1, pp. 89–97.

[5] Nilawati, P. A., Subandi, and Utomo, Y. 2016. Keefektifan Pembelajaran Interkoneksi Multipel Representasi dalam Mengurangi Kesalahan Konsep Siswa pada Materi Stokiometri. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, Vol 1, No 11, pp. 2076–2082.

6. Syahri, W. and Yusnadar, Y. 2022. Pengembangan E-Book Materi Gas Ideal Berbasis Multipel Representasi Menggunakan 3D Pageflip. *Journal of The Indonesian Society of Integrated Chemistry*, Vol 14, No 1, pp. 1–9.

7. Andromeda, B., Djudin, T., and Maria S., H. T. 2017. Analisis Kemampuan Multirepresentasi Siswa pada Konsep-konsep Gaya di Kelas X SMA Neegeri 3 Pontianak. *Jurnal Pendidikan dan Pembelajaran Khatulistiwa (JPPK)*, Vol 6, No 10, pp. 1–16.

8. Karlina, A. 2022. Profil Kemampuan Pemecahan Masalah Matematika Ditinjau Dari Gaya Kognitif Siswa. *Jurnal Math-UMB.EDU*, Vol 9, No 3, pp. 149–155.

9. Imamuddin, M. and Isnaniah, I. 2018. Profil Kemampuan Spasial Mahasiswa Camper Dalam Merekonstruksi Irisan Prisma Ditinjau Dari Perbedaan Gender. *Jurnal Matematika dan Pembelajaran*, Vol 6, No 1, pp. 31–39.

10. Smith, K. C., Nakhleh, M. B., and Bretz, S. L. 2010. An expanded framework for analyzing general chemistry exams. *Chemistry Education Research and Practice*, Vol 11, No 3, pp. 147–153.

11. Helsy, I. and Andriyani, L. 2017. Pengembangan Bahan Ajar Pada Materi Kesetimbangan Kimia Berorientasi Multipel Representasi Kimia. *JTK (Jurnal Tadris Kimiya)*, Vol 2, No 1, pp. 104–108.

12. Abbott, M. L. 2011. *Understanding Educational Statistics Using Microsoft Excel and SPSS*. Canada: Wiley.

13. Zahro', S. F. and Ismono. 2021. Analisis Kemampuan Multirepresentasi Siswa Pada Materi Kesetimbangan Kimia di Masa Pandemi Covid-19. *Chemistry Education Practice*, Vol 4, No 1, pp. 30–39.

14. Safitri, L., Winarti, A., and Suharto, B. 2020. Analisis Pemahaman Konsep Makroskopik-Submikroskopik-Simbolik Menggunakan Pendekatan Submikroskopik Pada Materi Larutan Asam Basa. *JCAE (Journal of Chemistry And Education)*, Vol 4, No 1, pp. 16–23.

15. Sunyono, Yuanita, L., and Ibrahim, M. 2013. Efektivitas Model Pembelajaran Berbasis Multipel Representasi dalam Membangun Model Mental Mahasiswa Topik Stoikiometri Reaksi. *Pendidikan Progresif*, Vol 3, No 1, pp. 65–79.

16. Azizah, N. L., Mahardiani, L., and Yamtinah, S. 2022. Analisis Miskonsepsi Dengan Tes Diagnostik Two-Tier Multiple Choice Dan in-Depth Interview Pada Materi Asam Basa. *Jurnal Pendidikan Kimia*, Vol 11, No 2, pp. 168–177.

17. Fajrin, S., Haetami, A., and Marhadi, M. A. 2020. Identifikasi Kesulitan Belajar Kimia Siswa Pada Materi Pokok Larutan Asam Dan Basa Di Kelas Xi Ipa2 Sma Negeri 1 Wolowa Kabupaten Buton. *Jurnal Pendidikan Kimia FKIP Universitas Halu Oleo*, Vol 5, No 1, pp. 27–34.

18. Gilbert, J. K. and Treagust, D. 2009. *Multiple Representation in Chemical Education*. Netherlands: Springer Dordrecht.

19. Sarastuti, R. D., Hambali, H., and Separen. 2022. Studi Komparatif Karakter Kreatif Pembelajaran Online Mata Pelajaran PKn Antara Siswa Laki-laki dan Perempuan di SMA Negeri 1 Singkep. *Journal of Science and Education Research(JSER)*, Vol 1, No 2, pp. 6–11.

20. Wahyudiati, D. 2021. Eksplorasi Sikap Ilmiah dan Pengalaman Belajar Calon Guru Kimia Berdasarkan Gender. SPIN: *Jurnal Kimia & Pendidikan Kimia*, Vol 3, No 1, pp. 45–53.

21. Fatimah, S. 2017. Analisis Pemahaman Konsep IPA Berdasarkan Motivasi Belajar, Keterampilan Proses Sains, Kemampuan Multirepresentasi, Jenis Kelamin, dan Latar Belakang Sekolah Mahasiswa Calon GURU SD. *Jurnal Inovasi Pendidikan dan Pembelajaran Sekolah Dasar*, Vol 1, No 1, pp. 57–70.

22. Tunnajch, N. F. and Gunawan. 2021. Analisis Kemampuan Pemecahan Masalah Matematis Siswa dalam Menyelesaikan Soal Berbasis Kontekstual pada Materi Trigonometri Ditinjau dari Perbedaan Gender. *MATH LOCUS: Jurnal Riset dan Inovasi Pendidikan Matematika*, Vol 2, No 1, pp. 7–14.