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THE APPLICATION OF MY MAMOVONO TECHNIQUE TO ENHANCE MALAYSIAN PRE-UNIVERSITY STUDENTS' MASTERY OF THE MOLE CONCEPT

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ABSTRACT

The MY MAMOVONO technique was created as an innovative way to improve pre-university students' ability to master the mole concept. The Malaysian pre-university students mentioned that they were confused by the formulas they needed to remember. The technique required them to build a card that contained the four (4) formulas of the mole concept using their creativity. Consequently, the students performed better post-intervention than in the pre-intervention phase. The paired sample t-test analysis revealed that the mean difference (24.44) between the students' post-intervention mean (82.78; SD = 10.46) and pre-intervention mean (58.33; SD = 7.48) is significant with $p < 0.001$. Moreover, the target students' post-intervention performance was significantly better than the minimum distinction mark – the difference between the post-intervention (82.78) and minimum distinction mark (70) is 12.78 with $p < 0.001$. The MY MAMOVONO technique positively impacted the students' level of understanding.

Contribution/ Originality: The study originates an innovative teaching and learning method for the mole concept - MY MAMOVONO technique. It is suitable to be applied for secondary and pre-university level chemistry.

1. INTRODUCTION

"Mole Concept" is a fundamental topic in physical chemistry. Before enrolling in a pre-university programme, science students in Malaysia learn the subject in Form 4 (Ministry of Education, 2018). The topic is taught in the first chapter of semester one (1), both at matriculation colleges (Matriculation Division, 2020) and Form 6 institutions (Malaysian Examinations Council, 2020). Several studies suggested that ideas like the calculation of mole and the expression of electronic equations are the most difficult for non-chemistry experts like students (Johnstone, 2000). Other researchers such as Johnstone (1991), Kimberlin and Yezierski (2016), and Ramesh, Rauf, and Fadzil (2020) also found that the mole concept was a difficult concept to be understood by their participants. Students as novice learners require the same level of expertise as professional chemists to fully grasp complex and abstract chemistry concepts (Nor & Noraihan, 2009). Errors in calculating the number of the mole will have an impact on subsequent calculations and thus affecting the students' marks in the examination.

Over the many years of teaching the topic, the authors noticed that their students would have difficulty determining the correct formula for a specific mole concept problem despite having at least two (2) hours of learning the mole concept in class. They perceived this as a worrying trend as the idea is fundamental knowledge

that students must master before moving forward to succeeding chemistry chapters. For that reason, they assumed that the existing teaching and learning (t&l) techniques could not assist students in learning the mole concept effectively. The literature indicates that using innovative t&l strategies can enhance students' level of understanding in chemistry. For example, Kadum (2022) administered the POL: PLL & PLR method to improve students' knowledge of acidic buffer solutions via pre-lesson learning activities and active post-lesson reflections. In a different study, Kadum, M., Joanes, and Lee (2022) managed to significantly improve students' information retention ability of the water electrolysis redox equation through the implementation of FLEMONIC. Ergo, inspired by those studies, the authors devised a technique called MY MAMOVONO to enhance pre-university students' level of knowledge of the mole concept.

2. REFLECTIONS ON T&L

In this section, two (2) forms of reflection are presented as the study background – teachers' reflections and students' reflections. Kadum et al. (2022) employed the same approach to conceptualise their study's problem statement and thus used the information to design their t&l innovation.

2.1. Teachers' Reflections

As mentioned earlier, the mole concept is an essential topic in chemistry as it provides the basic information and skills that will allow students to learn succeeding chemistry topics effectively. Failing in mastering the concept will jeopardise students' performance in the examination. About 15% of the mark is allocated in the written exam and 15% in the laboratory report assessment on this topic.

Typically, chemistry teachers would use the "mole triangle" to teach the concept. Figure 1 shows an example of the teaching method. After teaching using the conventional way, the authors noticed that students were still confused about applying formulas that they had learned.

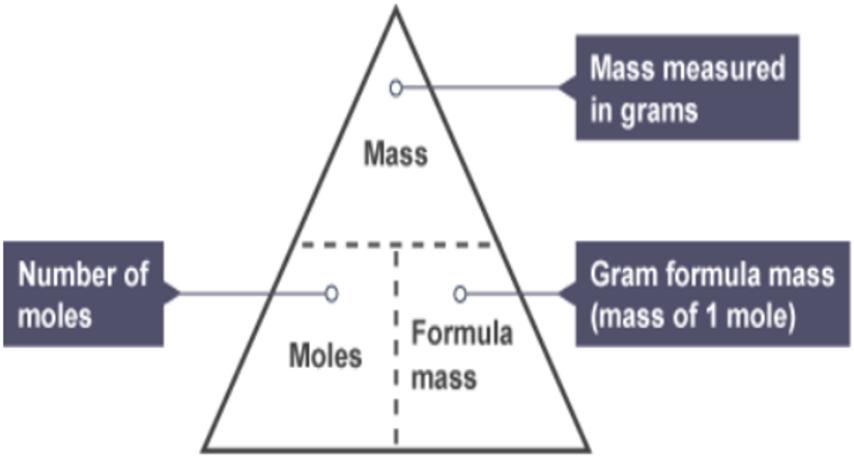

Figure 1. An example of the "mole triangle".
Source: BBC Bitesize (2022).

2.2. Students' Reflections

Many students who had used the "mole triangle" were still facing an uphill challenge in solving calculation-based mole concept problems. To comprehend the situation, the authors interviewed several students, and they discovered that the problem had been an issue since the students were in secondary school, i.e., Form 4. Furthermore, the students revealed that they understood the formulas but were confused about deciding which formula had to be used for a particular question. Others responded that they had difficulty memorising the formulas and did not know which unit was supposed to be used for the calculations. These are some excerpts of the students' responses verbatim; pseudonyms are used to conceal their identities:

Sylvia stated:

"...this topic was easy to be understood when I was learning about it in class, but it was easy for me to get confused too. Especially at the exchange of units in every formula when answering related questions."

Nurain responded:

"...in this topic, it was a little bit confusing to me on which specific formula to use to answer the given question correctly. Usage of units was also not convincing to me."

Andrea echoed:

"...there were several formulas that I did not fully understand and yes… confusing to pick which one was the correct one."

Azwan shared:

"...there were several formulas that I did not fully understand and yes… confusing to pick which one was the correct one."

From the excerpts, it is clear that the students had a weak mastery of the mole concept. The major problem was an incorrect formula was used to solve a particular question.

3. RESEARCH FOCUS

Students must know four (4) formulas in solving mole concept problems. Herewith are the formulas (Yip, 2007):

i. Converting from "number of moles (mol)" to "number of particles (N)":
Number of moles (mol) x Avogadro's constant (N_A) = number of particles (N)
**Avogadro's constant: 6.022×10^{23} mol^{-1}*

ii. Converting from "number of moles (mol)" to "mass (g)":
Number of moles (mol) x molar mass (g/mol) = mass (g)

iii. Converting from "number of moles (mol)" to "molar volume of gas (dm^3)":

- At standard temperature and pressure (STP)
Number of moles (mol) x 22.4 dm^3 mol^{-1} = molar volume of gas (dm^3)
- At room temperature (RT)
Number of moles (mol) x 24.0 dm^3 mol^{-1} = molar volume of gas (dm^3)

As mentioned in the preceding paragraphs, confusion in the usage of formulas was the top challenge that our students were facing. Even though they would be able to memorise the formulas, the problem was they failed to apply them to solve relevant questions. Ergo, their examination marks would be negatively affected.

The authors focused on this issue as it did not merely affect the t&l process, but it potentially hindered the students' holistic development in chemistry. They realised that encouraging the students to make their notes would empower their learning process, facilitating better memorisation and comprehension. Thus, the authors trained the students to build their own MY MAMOVONO cards to write the four (4) mole concept formulas for this classroom research. Using such an approach motivated the students to engage more naturally with the concept; before the technique, they were visibly discouraged and did not find joy in learning the mole concept. MY MAMOVONO is the abbreviation for – "MY = My/Mine", "MA = Mass (g)", "MO = Number of moles (mol)", "VO = Molar volume of gas (dm^3)", and "NO = Number of particles".

4. RESEARCH OBJECTIVES

4.1. General Objective

To enhance pre-university students' mastery in the mole concept using the MY MAMOVONO technique.

4.2. Specific Objectives

1. To improve the pre-university students' marks in mole concept test/examination using the MY MAMOVONO technique.
2. To improve the pre-university students' perceptions of the mole concept using the MY MAMOVONO technique.

5. SCOPE AND RESEARCH LIMITATIONS

This classroom research merely focused on using MY MAMOVONO cards built by students' creativity. The new instructional method was limited to the selected topic, i.e., the mole concept. Thus, the effect of applying the technique to other topics in chemistry or other science subjects cannot be extrapolated based on the findings of this study. Another limitation, the results that emerged from the collected data of the current classroom research was limited to the target group and thus cannot be generalised to other populations.

6. TARGET GROUP

The authors recruited eighty (80) pre-university students for the initial stage of the study – twenty-seven (27) from Class X, twenty-five (25) from Class Y, and twenty-eight (28) from Class Z. They were science module students from a local pre-university college located in the Federal Territory of Labuan. The students sat for a diagnostic test during this stage, and the authors identified eighteen (18) students who scored below the passing line. Hence, these students were part of the target group. Table 1 shows the grading system explicitly designed for this classroom research. Table 2 presents the number of male and female students selected as the target group. Table 3 shows the students' *Sijil Pelajaran Malaysia* (SPM) chemistry grades.

Table 1. The grading system of the classroom research.

Mark Range	Grade	Level
100 – 80	A	Distinction
79 – 75	A-	
74 – 70	B+	
69 – 65	B	Merit
64 – 60	B-	
59 – 55	C+	Pass
54 – 50	C	
49 – 45	C-	Fail
44 – 40	D	
39 – 35	E	
34 – 0	F	

Table 2. The number of target students based on gender.

Gender	Number of Students
Male	4
Female	14
Total	18

Table 3. Target students' SPM chemistry grades.

Mark Range	Grade	Number of Students
70 – 74	B+	1
60 – 64	C+	4
50 – 59	C	2
45 – 49	D	6
40 – 44	E	5

From Table 3, it can be seen that five (5) of them obtained an E grade for SPM chemistry, i.e., they did not pass the subject. Thirteen (13) got a passing grade, with one (1) student obtaining a B+ grade in SPM chemistry.

7. RESEARCH DESIGN

This classroom research employed the investigative approach as follow.

i. *Pre-intervention* – The targeted students were given a set of questions that carried twenty (20) marks in total. These questions had to be answered within thirty (30) minutes. The difficulty level for the pre-intervention test was set to be the same difficulty level as the diagnostic test.

ii. *Intervention* – The t&l using MY MAMOVONO technique. The target students were allowed to creatively create their cards that contained the mole concept's four (4) formulas.

iii. *Post-intervention* – The target students were given the same set of questions as the pre-intervention test. The set carried twenty (20) marks in total, and the students were allotted thirty (30) minutes to answer all questions.

iv. *Survey* – The target students were instructed to provide feedback. They filled up a survey form.

7.1. Data Collection Method

The authors collected data via three (3) sets of questions:

i. Pre-intervention questions – The purpose of these questions was to obtain information about the target students' level of the mole concept mastery.

ii. Post-intervention questions – Using the post-intervention test, the authors could see the effect of administering the MY MAMOVONO technique on the students' mastery level

iii. Survey – The students' perceptions toward the learning process of the mole concept were gauged using a survey form.

Table 4 presents the timeline for implementing the classroom research project in detail.

Table 4. The classroom research project's timeline.

No.	Action	Date of Implementation
1.	Briefing	3 July 2019
2.	Pre-intervention test	5 July 2019
3.	Data analysis	12 July 2019
4.	Interventuon: MY MAMOVONO	19 July 2019 & 26 July 2019
5.	Post-intervention test	2 August 2019
6.	Survey	9 August 2019
7.	Data analysis	16 August 2019

7.2. Initial Observation

As mentioned earlier, the purpose of the pre-intervention was to identify the target students' level of understanding of the mole concept. The session tested them with questions that carried twenty (20) marks in total. They were given thirty (30) minutes to complete those questions. The students were visibly struggling to complete the task. Three (3) students left the session before the allocated time was up. The authors asked those who left early whether it was okay or otherwise, and they answered the former.

7.3. Intervention Phase

After the test data from the pre-intervention were analysed, the authors proceeded to implement the intervention phase. The pre-intervention results were not disclosed to the target students. Moreover, the students' works were not returned. This was deliberate as the authors wanted to look at the effectiveness of the MY MAMOVONO technique. Two (2) workshops were held as part of the intervention phase.

i. "Jelas" Workshop (Bengkel Jelas) – The students were provided with a thorough explanation about the four (4) formulas of the mole concept and how to use them in solving relevant problems.

ii. "Bina" Workshop (Bengkel Bina) – The authors worked closely with the students in assisting them in building their MY MAMOVONO cards. This was the synergy between the authors and the target students. It reinforced the authors' role as facilitators in the student-centred learning process. Figure 2 presents several samples of the students' MY MAMOVONO cards.

Figure 2. Samples of students' MY MAMOVONO cards.

7.4. Evaluation

Through the diagnostic test, pre-intervention, and post-intervention, the MY MAMOVONO technique was seen to be an effective t&l approach. The analysis of the post-intervention data revealed that the students' ability to answer questions regarding the mole concept had increased. Figure 3 shows the difference between pre-intervention and post-intervention marks using a scatterplot graph. From the figure, it can be seen that all target students' post-intervention marks were higher than their pre-intervention marks.

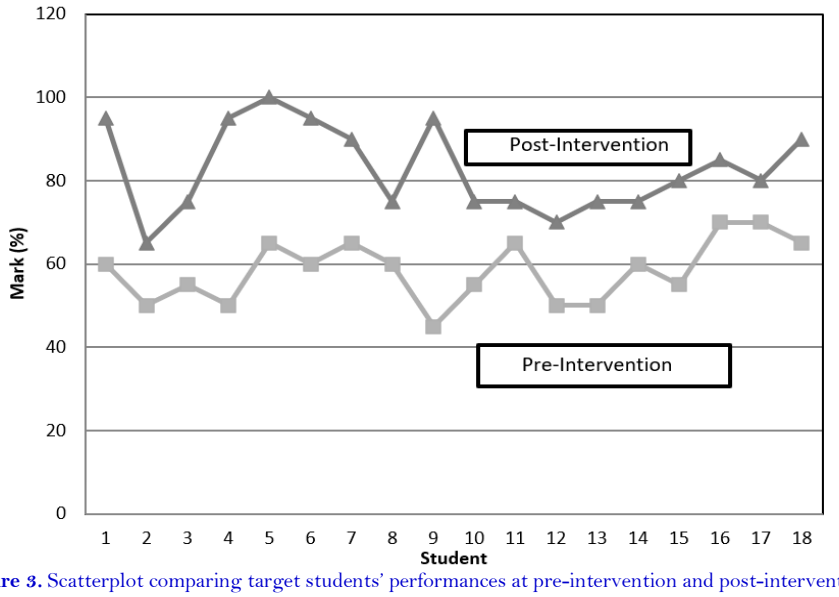

Figure 3. Scatterplot comparing target students' performances at pre-intervention and post-intervention.

Table 5 further substantiates that the MY MAMOVONO technique enhanced the weak students' ability to answer mole concept questions correctly. In the pre-intervention test, most students scored mediocre grades. Others scored below 50%, which was considered fail based on the grading system of the current study. After the intervention was implemented, the post-intervention results revealed that most students passed the test, and ten (10) of them passed with flying colours.

Table 5. Comparison of the target students' performances in pre-intervention and post-intervention.

Mark Range	Grade	Pre-Intervention		Post-Intervention	
		No. of Students	%	No. of Students	%
0 – 49	Fail	1	5.6	0	0
50 – 54	C	4	22.2	0	0
55 – 59	C+	3	16.7	0	0
60 – 64	B-	4	22.2	0	0
65 – 69	B	4	22.2	1	5.6
70 – 74	B+	2	11.1	1	5.6
75 – 79	A-	0	0	6	33.3
80 – 100	A	0	0	10	55.5

The authors wanted to know whether the target students' post-interventions marks were significantly higher than their pre-intervention marks. Thus, they ran a paired samples t-test analysis using the JASP version 0.16.1, a freeware statistical analysis tool developed by the University of Amsterdam (Love et al., 2019). Several studies have verified the tool's reliability in computing statistical data and thus providing accurate outcomes (Han, Park, & Thoma, 2018; Marsman & Wagenmakers, 2017; Quintana & Williams, 2018; Zolotov, Reznik, Bender, & Isralowitz, 2020). It was confirmed that the target group's post-intervention performance (i.e., mean = 82.78) was statistically significant than the pre-intervention (i.e., mean = 58.33); the mean difference is 24.44 and the $p < 0.001$. Table 6 presents the descriptive findings, and Table 7 shows the inferential analysis outcome. Figure 4 shows the raincloud plots of the data analysis. As stated by Allen, Poggiali, Whitaker, Marshall, and Kievit (2019), "These raincloud plots can visualize raw data, probability density, and key summary statistics such as median, mean, and relevant confidence intervals in an appealing and flexible format with minimal redundancy". The authors of this study utilised the JASP statistical tool to generate the raincloud plots.

Table 6. Descriptive findings.

Measurement	N	Mean	SD	SE
Pre-Intervention	18	58.33	7.48	1.76
Post-Intervention	18	82.78	10.46	2.47

Note: SD = standard deviation, SE = standard error.

Table 7. Paired samples t-test outcome.

Measurement 1	Measurement 2	t	df	*p*	Mean Difference	SE Difference
Pre-Intervention	Post-Intervention	9.03	17	< 0.001	24.44	2.708

Note: Significance $p < 0.001$.

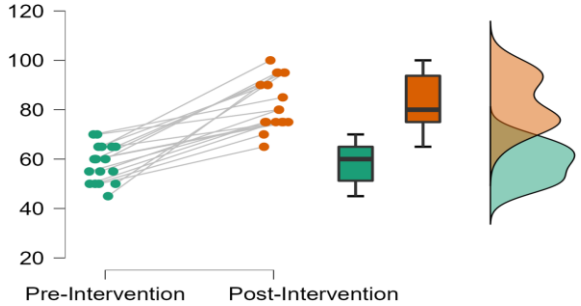

Figure 4. Raincloud plots comparing the students' pre-intervention and post-intervention marks.

From Table 5, it can be seen that the target students managed to score above the passing line. Thus, the authors wanted to know whether the group had performed significantly higher than the minimum distinction mark – the distinction range = 70 – 100 (refer to Table 1). A one-sample t-test analysis was administered using the freeware statistical analysis tool JASP version 0.16.1. to investigate the authors' notion. The target group's post-intervention mean (82.78) is higher than the minimum distinction mark (70). The mean and the minimum distinction mark difference is 12.78 with $p < 0.001$. Therefore, it is confirmed that the target students' post-intervention performance was significantly higher than the minimum distinction mark. Table 8 summarise the inferential outcome. Figure 5 represents the post-intervention raincloud plots, and it can be seen that one (1) student scored below 70, but most of the area of the cloud is greater than 70.

Table 8. One-sample t-test outcome.

Measurement	t	df	*p*	Mean Difference
Post-Intervention	5.18	17	< 0.001	12.78

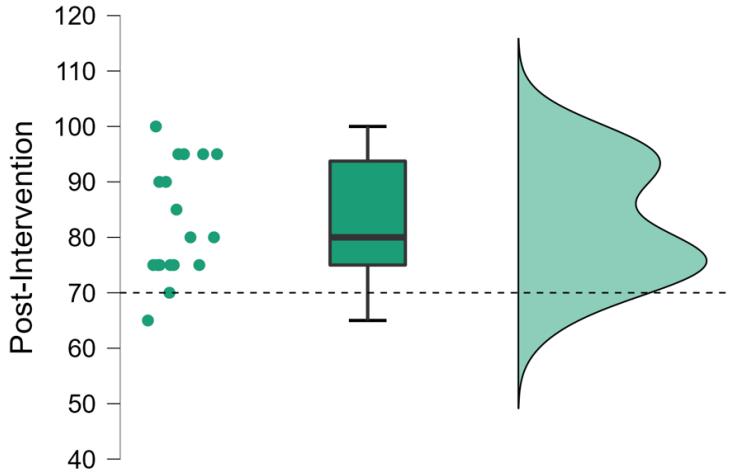

Figure 5. Raincloud plots of the target group's post-intervention performance.

Table 9 and Figure 6 show the analysis of the feedback gathered via survey forms. There were five (5) survey statements that the students had to respond using a 4-point Likert scale – "Disagree (D) = 1", "Quite Disagree (QD) = 2", "Quite Agree (QA) = 3", and "Agree (A) = 4". Three (3) statements, i.e., S1(-), S2(-), and S3(-) were asking the students to rate their level of agreement on negative learning experiences before the implementation of MY MAMOVONO – "...was difficult to understand", "...formulas of the mole concept were difficult to memorise", and "...quickly get confused". Whereas, two (2) statements, i.e., S4(+) and S5(+) evaluated the students' level of agreement on positive learning experiences after they learned the mole concept using the new instructional strategy – "...facilitated the memorising process" and "...helped me to understand the application of each formula".

From the analysis of the survey, it is apparent that the MY MAMOVONO technique was able to help them to understand, remember, and hence utilise the correct formula in solving a certain mole concept problem. For the positive learning experience post-intervention, S4(+) statement – 77.78% agreed, and 22.22% quite agreed (mean = 3.78; SD = 0.428). No students reported to disagree nor quite disagree. The other positive learning experience, S5(+) statement – 72.22% agreed, and 27.78% quite disagreed (mean = 3.72; SD = 0.461). Like S4(+), no students reported to disagree nor quite disagree with S5(+).

These findings contrast with the negative learning experiences, as shown in Table 9 and Figure 6. For the S1(-) statement, 22.22% of students agreed, and 55.56% were quite agreed. Only 22.22% disagreed, and none of the students disagreed with the negative learning experience before MY MAMOVONO. S1(-)'s mean 3.00 with SD equals 0.686. For the S2(-) learning experience, 38.89% were agreed, and 50.00% were quite agreed. Only 11.11% of

the students quite disagreed, and none of them reported disagreeing with the statement. S2(-)'s mean 3.28, SD computes to 0.669. For the third negative learning experience before MY MAMOVONO, 55.56% were agreed with S3(-), and 33.33% were quite agreed. Only 11.11% of the students quite disagreed, and none disagreed with the statement. S3(-) has a mean of 3.44 and an SD value of 0.705.

Figure 6 aptly presents the visualisation of the target group's shift in the learning experience of the mole concept. It shows that the new instructional method has nurtured positive perceptions of the mole concept learning amongst the pre-university students who partook in the study.

Table 9. Survey analysis – five (5) statements.

Tag	Statement	No. of Responses			
		1 Disagree (D)	2 Quite Disagree (QD)	3 Quite Agree (QA)	4 Agree (A)
S1(-)	Before learning the MY MAMOVONO technique, I felt that the mole concept in mol calculation was difficult to understand.	0 (0.00%)	4 (22.22%)	10 (55.56%)	4 (22.22%)
S2(-)	Before learning the MY MAMOVONO technique, I felt that the mole concept formulas were difficult to memorise.	0 (0.00%)	2 (11.11%)	9 (50.00%)	7 (38.89%)
S3(-)	Before learning the MY MAMOVONO technique, I would quickly get confused when deciding on the correct formula for a particular question.	0 (0.00%)	2 (11.11%)	6 (33.33%)	10 (55.56%)
S4(+)	The MY MAMOVONO technique facilitated the memorising process of the four formulas of the mole concept.	0 (0.00%)	0 (0.00%)	4 (22.22%)	14 (77.78%)
S5(+)	The MY MAMOVONO technique helped me understand the application of each formula of the mole concept.	0 (0.00%)	0 (0.00%)	5 (27.78%)	13 (72.22%)

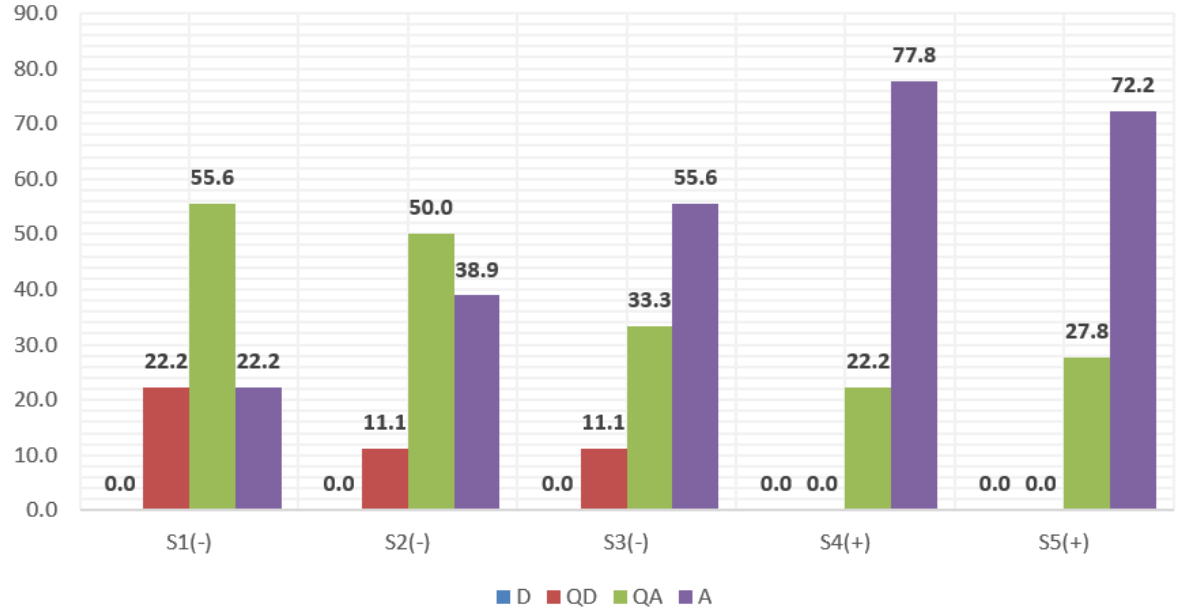

Figure 6. Visualisation of the target group's learning experience before and after MY MAMOVONO.

8. RESEARCH REFLECTION

Two (2) vital elements were intricately linked in the teaching and learning process – the synergy between the authors and the target students. As teachers, the authors facilitated the learning process, and the students acted as active learners. They did not just sit and accept the transmitted knowledge passively like a sponge, but they were involved in the process of making their own MY MAMOVONO cards (refer to Figure 2).

This classroom research had benefited not only the pre-university students. They participated in the study and taught teachers always to be aware of their needs, especially the mole concept. Meor and Nurhidayah (2009) stated that learning chemistry concepts and getting them right is not easy. After going through the research stages, we agreed with her statement. Moreover, chemistry as a constantly developing and evolving field is a fertile ground for students' misconceptions, and thus it can cause students to fail in mastering the subject. For that reason, this classroom research was developed to help our students to deal with misconceptions about the mole concept.

8.1. Strengths & Weaknesses of the Classroom Research Project

The project encouraged the students to use their creativity to build their own MY MAMOVONO cards, and this served as a great platform to engender a fun learning atmosphere. Weak students had difficulty recalling the information that they had learned in class. The project had helped them remember better as they were actively involved in creating their learning aids for the mole concept – this, to an extent, was personalised learning.

The outcome of the classroom research project revealed that our students who initially scored merely mediocre grades managed to get excellent grades after participating in the MY MAMOVONO project. Nevertheless, there were several weaknesses that the authors identified. Firstly, the project may be time-consuming for teachers to implement, particularly in a setting whereby the learning schedule is packed. Secondly, teachers who want to implement the new instructional method may have to invest some money in getting the raw materials such as coloured papers, coloured pens, glitters, et cetera.

9. CONCLUSION

MY MAMOVONO technique enhanced the pre-university students' mastery of the mole concept and thus is reflected in their post-intervention marks. The significant increase in marks showed that encouraging the students to use their creativity in chemistry learning is a powerful tool that teachers can apply in the classroom. Different individuals possess unique ways to memorise information. Some utilise a rhyming technique to help them learn; some use singing or poetry. Nevertheless, the most important thing is that mnemonic serves to remember information easily. Among the mnemonic strategies are the rhyming of relevant acronyms and simplifying information. Therefore, we used the same approach for MY MAMOVONO, which helped the students learn the concept of mole better than using conventional techniques.

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Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Both authors contributed equally to the conception and design of the study.

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