The Efficacy of “POL: PLL & PLR” Method to Enhance Pre-University Students’ Understanding of Buffer Solution

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ABSTRACT

The purpose of this classroom research was to see whether the method of Portfolio of Learning (POL): Pre-Lesson Learning & Post-Lesson Reflection (PLL & PLR) could enhance understanding of a chemistry concept, i.e., buffer solution, amongst pre-university students from a local institution located in the Federal Territory of Labuan, Malaysia. The sample was amongst the researcher’s tutorial group students; thirty-four (34) students in total. Initial observation showed that the students were struggling to grasp even the most basic chemistry concepts due to their poor learning strategies/skills. Therefore, this had served as the impetus for this research to be conducted. The group of students was equally divided into two (2) groups; the control group (CG) & the experimental group (EG). The T-Test analysis of the collected data showed a significant difference between the CG’s mean score and the EG’s mean score; $t = 4.211$, $p = 0.000216$ ($p < 0.001$). Therefore, the study successfully validated the effectiveness of the proposed method of learning for enhancing the level of understanding of buffer solutions.

Contribution/Originality: The paper’s primary contribution is finding nurturing metacognitive faculty amongst students in chemistry subject is essential for student scholastic achievement. Moreover, it originates an innovative instructional method – Portfolio of Learning (POL): Pre-Lesson Learning (PLL) & Post-Lesson Reflection (PLR). The method can be used by other educators of different STEM fields as well.

1. Introduction

Chemistry is regarded as the science that deals with the composition, structure, and properties of substances and with the transformations that they undergo. Modern chemistry concepts are the derivation of humans’ intellectual development of practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation. Ihde (1984) in his book entitled “Development of Modern Chemistry” includes extensive and comprehensive writing on how “chemistry” has progressed both etymology and conceptually.

According to [Ihde \(1984\)](#), the development of chemistry concepts cannot be assumed as development only in the past two centuries as the fundamentals of the discipline have accumulated from the day that primitive man mastered fire. Nevertheless, the chemistry concepts which are being learned and taught at present-day primary, secondary and tertiary levels of education have emanated from the work of the pneumatic chemists following the discoveries concerning gases after 1750 ([Ihde, 1984](#)).

“Chemistry” as we all know is part of any nation’s education framework especially for the primary and secondary level institutions and at the university level, chemistry is optional for students who are pursuing a chemistry degree or any degree in which the concepts of chemistry are incorporated in some of the taught modules. Students, nonetheless, prior to embarking upon university-level education, are expected to go through a foundation programme in which chemistry is part of its syllabi. Chemistry concepts have been deemed as difficult to be comprehended by students ([Nakhleh, 1992](#); [Kousa et al., 2018](#); [Nartey & Hanson, 2021](#)). [Johnstone \(2000\)](#) expounded that the difficulties may lie in human learning as well as in the intrinsic nature of the subject. He proceeded by stating that novice learners are unable to balance the three (3) levels of thought required for understanding chemistry concepts; the macro and tangible; the sub-micro atomic and molecular; and the representational use of symbols and mathematics ([Johnstone, 2000](#)).

2. Research Background

This research was designed with the intention to emphasise the beneficial impact of systematic and comprehensive reflection subsequent to a lesson on students’ scaffolding of chemistry concepts. Lesson reflection is seen as one of the important tools in teaching and learning as it enables students to elevate their thinking skills ([White & Frederiksen, 1998](#); [Papleontiou-Louca, 2003](#)). In 2002, at the 4th World Conference of the Consortium for Educational Development in Higher Education, [King \(2002\)](#) delivered an identical argument on embracing the efficacy of reflection in promoting significant learning. In his argument, he argued that reflective learning possesses the power to facilitate significant learning and understanding in the more unstructured areas of knowledge domains ([King, 2002](#)). Apart from [King \(2002\)](#), other educational researchers such as [Baird et al. \(1991\)](#) have found that collaborative reflection could enhance teaching and learning of science by generating desirable cognitive, metacognitive, and affective outcomes.

The other purpose of this research was to stress the significant impact of students learning a subject matter prior to a slot of learning it with a teacher in a class (pre-lesson learning). Several studies have indicated the importance of incorporating and nurturing post-lesson reflection skills in knowledge acquisition amongst students. However, scientific studies on pre-lesson learning are almost non-existent. Nonetheless, I personally believe that incorporating the skills of conducting systematic and comprehensive pre-lesson learning is equally paramount in order to assemble a student’s portfolio of learning (POL). The idea of encouraging students to devise a POL for enhancing their understanding of chemistry concepts has been inspired by the work of [Zubizarreta \(2009\)](#). He is a Professor of English and over the years he has been deeply passionate to help institutions across the United States (US) to improve on their teaching and learning qualities. In his development of learning portfolios, he focuses on a key point: in learning portfolios, students assume responsibility for documenting and interpreting their own learning. Through reflection, students make their thinking visible ([Zubizarreta, 2009](#)). Even though [Zubizarreta’s \(2009\)](#) developed idea of learning portfolios is intended to help social science students enhance their cognitive ability, nonetheless the essence of

his research is applicable in designing the POL for chemistry, i.e., in the case of the current study – buffer solution.

3. Research Objective

Students hold a negative perception of chemistry due to the intrinsic nature of the subject (Nakhleh, 1992; Johnstone, 2000; Kousa et al., 2018; Nartey & Hanson, 2021). Through the researcher's observation on his lesson reflections/reports that he recorded in his daily lesson plan (DLP), it was evident that his own students exhibited the same perception towards chemistry learning. Oftentimes, the students were overwhelmed by the inherent demands of the subject which required them to have a strong knowledge of mathematics as well as spatial thinking to visualise, for example, bonding formations and structure of molecules. In addition, they were equally frustrated with the pace of teaching of the subject which most of them thought was too fast or not enough since the number of concepts they need to take in.

As a teacher, the researcher agreed that the pace of teaching was considerably fast. However, at the same time, he believed that by employing an effective learning strategy, students would not only be able to understand the concepts; they would be able to possess more positive views on the subject to boot. Therefore, the research aimed to raise students' awareness on the advantage of devising comprehensive learning strategies and one of them is the pre-lesson learning (PLL) and post-lesson reflection (PLR) – Portfolio of Learning (POL).

4. Limitations of Research

The study was centred on thirty-four (34) students (target group) from two (2) tutorial groups (science modules). The students had been in the matriculation programme for about three (3) months when the study was conducted. Furthermore, it was limited to the students' ability to understand the concept of buffer solution. The result obtained through this research is limited to the target group and thus generalisation is limited as well.

5. Methodology of Research

To understand the issue of understanding chemistry concepts amongst the pre-university students, the researcher gathered feedback via a whole class consensus prior to ending a tutorial and a lecture session. The responses were recorded in the DLP and thus by looking at the feedback, it was apparent that one of the major contributors for the students' inability to comprehend chemistry concepts was due to poor learning strategy. Their weak understanding of even the basic concepts was clearly seen in the quality of their tutorial assignments, quizzes, and tasks. Plus, it was rather a challenging task for them to provide a response to questions that would demand them to think critically and creatively.

5.1. Sampling

The research involved thirty-four (34) science module pre-university students. The students were chosen based on their *Sijil Pelajaran Malaysia* (SPM) Chemistry results and Chemistry Diagnostic Test (CDT) results; they obtained a C or C+ for SPM Chemistry and a mark in the range of 20% - 60% for the CDT test. Seventeen (17) students from the sample were reserved as a control group (CG). The CG was exposed to the conventional

teaching method and acted as a comparison with the other seventeen (17) students who were taught with the POL: PLL & PLR method – experimental group (EG).

5.2. Subject Matter Selection

A chemistry topic was selected as part of the research in order to verify the effectiveness of POL: PLL & PLR. The researcher was aware that any chemistry topic could be picked. However, it was ensured that by the time the test was conducted on the chosen week, both groups (CG & EG) had not learned the topic neither in their lecture or tutorial sessions (they were “topic neutral” prior to the test). This was to establish a research outcome that could entirely reflect the purposes and research methodology of this study.

“Buffer Solution” was opted for the research. Due to the limited amount of time allocated for the test, only the acidic part of the “Buffer Solution” was delivered to both groups and therefore utilised as the content of the quiz given during “Quiz Day”.

The “Acidic Buffer Solution” subject matter was consisted of:

I. Action of an Acidic Buffer Solution.

The example of an acidic buffer solution made up from mixing a weak organic acid, ethanoic acid with its corresponding salt, sodium ethanoate was used to explain the action of an acidic buffer solution.

The partial dissociation of ethanoic acid

The complete dissociation of sodium ethanoate

II. Henderson-Hasselbach Equation & pH of Buffers.

$$\text{pH} = \text{pK}_a + \log \frac{[\text{CONJUGATE BASE}]}{[\text{WEAK ACID}]}$$

The Henderson-Hasselbach Equation for Acidic Buffer Solution

5.3. Implementation of the POL: PLL & PLR

The implementation was done in a length of four (4) days. The experimental group was involved in all four days whereas the control group was involved in “Day 2” and “Day 4” only. Each day consisted of different activities which could either be fully student-centred or teacher-centred or a mixture of both.

5.3.1. DAY 1: Pre-Lesson Learning (PLL) for “Acidic Buffer Solution”

The experimental group was gathered in a tutorial room and prior to the PLL session, the students were instructed to bring as many as possible resources to the session. The PLL session was completely student-centred, and the teacher solely functioned as a mentor or guide. For an introduction, they were briefed on what they needed to do for the PLL and subsequent to that they were given two (2) hours to run “mini-research” on “Acidic Buffer Solution”. The “mini-research” was a repertoire of activities that were interconnected

with one another: reading and analysing the contents, discussing with their peers, simplifying notes by taking important key points, and listing down questions they would want to be answered through the teacher-centred session during the “Lesson Day”. The researcher observed students engaging in lively discussions with their peers and they managed to build comprehensive simplified notes as a preparation for the “Lesson Day”. When the PLL session was coming to an end, the researcher gathered feedback and it was encouraging to know that the students enjoyed the activities. As a result, they were excited for the “Lesson Day”. The excitement was due to the curiosity sparked via getting the students to generate and to compile questions from their “mini-research”.

5.3.2. DAY 2: Lesson Day for “Acidic Buffer Solution” & Post-Lesson Reflection (PLR)

Day 2 was divided into two (2) parts; First Part – Subject Matter Lecture (teacher-centred) & Second Part – the employment of PLR. Both groups (CG and EG) were involved in the “Subject Matter Lecture” on “Acidic Buffer Solution”. During this session, the concepts and corresponding mathematical calculations were delivered in a didactic manner. It was observed that the EG was more attentive than the CG during the session. All students were instructed to write down important notes and they were encouraged to study the notes for the upcoming “Quiz Day”. After the “Subject Matter Lecture” had finished, the CG was instructed to dismiss and the EG stayed in the lecture hall to initiate the PLR session. During the session (student-centred & teacher-centred), it could be seen that the students were highly engaged in their learning, and they gained a greater level of satisfaction as their questions from the PLL session were mostly answered. The session encouraged them to chisel out those “messy corners” of the knowledge they had gathered through the “mini-research” they did on Day 1.

5.3.3. DAY 3: Post-Lesson Reflection (PLR) for “Acidic Buffer Solution”

The PLR session for Day 3 was similar to what the experimental group had done on Day 2. The only difference was, PLR on Day 3 was more to a student-centred activity where they convened in a tutorial room, and they had about an hour to improve on their notes.

5.3.4. DAY 4: Quiz Day

Both groups took the same quiz on the same day and venue. The “Buffer Solution” Quiz demanded the students to answer eight (8) multiple-choice questions (MCQs) and three (3) open-ended questions that lead to twenty-seven (27) marks in total. The students were given forty-five (45) minutes to answer the questions and they were given the liberty to hand in the quiz sheet even before the allocated time would end. There were ten (10) students leaving the quiz room before the allocated time was up and seven (7) of them were from the CG. Moreover, it was evident that the students from the CG were having a greater difficulty answering the given questions than their EG counterparts.

6. Analysis of Data & Outcomes

The students were graded based on the grading system designed specifically for this study. [Table 1](#) presents the grading system in details.

Table 1: Grading System

GRADE	LEVEL
A, A- & B+	Distinction
B & B-	Merit
C+ & C	Pass
D+, D, E & F	Fail

*Distinction, Merit & Pass are "PASS LEVELS"

Analysis of [Table 2](#) shows that the percentage of "Fail" amongst the students in the EG is 47% whereas the CG shows a percentage of "Fail" up to 94%. Only one (1) student (6%) from the CG obtained a Pass Level and therefore the highest quiz mark in the group; the student managed to get twelve (12) marks out of twenty-three (23) marks allocated (52%). On the other hand, the EG shows much more positive results in which nine (9) students (53%) obtained the passing levels; four (4) students (24%) gained Pass Level, three (3) students (18%) gained Merit Level, and two (2) of the students (12%) gained Distinction Level. None of the students from CG managed to get neither a Merit nor a Distinction Level. The highest quiz mark for the CG is 52% (C Grade) and the lowest mark for the group is 9% (F Grade). Whereas in the EG, the highest mark is 74% (B+ Grade) and the lowest mark is 22% (F Grade). When the two (2) lowest marks from both groups are compared, it can be seen that both of the marks are of the "F Grade" but the student who got an "F Grade" (lowest mark) in the EG did significantly better than the one from CG.

Table 2: Quiz Results of CG and EG

Level	EG	CG
Distinction	12%	0%
Merit	18%	0%
Pass	24%	6%
Fail	47%	94%

To further substantiate the validity of the effectiveness of POL: PLL & PLR, a T-Test analysis was done on the collected data. [Spatz \(2008\)](#) in his book explains T-Test as a statistical examination of two (2) population means. A 2-sample T-Test examines whether 2 samples are different is commonly used when the variances of two normal distributions are unknown and when an experiment uses a small sample size. For this study's T-Test analysis an independent T-Test was administered to compare the mean scores of both groups. The difference in the mean scores was able to determine whether the outlined hypothesis for this research could be verified or otherwise; to prove that the POL: PLL & PLR method improves students' understanding of buffer solution concept.

Analysis of [Table 3](#) shows a mean difference of 20.360 between the mean scores of the groups. This value is significant due to the $t = 4.211$, $p < 0.001$ values being obtained.

Table 3: Independent T-Test of The Difference in the Mean Scores Between CG and EG

Test	N	Mean Score	Standard Deviation	Mean Difference	t VALUE	Sig.
EG	17	49.18	15.150	20.360	4.211	0.0002
CG	17	28.82	11.944			

*Significant $p < 0.001$

The t value obtained from the T-Test is virtually bigger than the p-value and therefore it can be concluded that the mean scores of both groups are significantly different (Spatz, 2008). Ergo, the quantitative analysis of Table 2 and Table 3, it proves that the POL: PLL & PLR is able to elevate students' level of understanding of the buffer solution concept.

7. Suggestions

The study has given good outcomes and therefore it has brought forth the positive impact of devising a systematic and comprehensive learning strategy. Most importantly it has proven the effectiveness of the method which has been employed for the current research. However, for future development, the size of the sample may be increased to further substantiate the data obtained through this research as conducting a statistical study on a bigger population may bring greater confidence in a designed method (Spatz, 2008). The method must be tested on other subject matters as well. Furthermore, questionnaires can be designed as an extension to qualitative and quantitative analysis. For this research, feedback collection and observations were the sources of the qualitative data.

8. Conclusion

Apart from verifying the significant impact of employing POL: PLL & PLR in order to understand a concept, the study at the same time hopes to raise the awareness of adapting oneself to a self-directed learning environment. The method provides an opportunity for students to develop their cognitive development not by being overly dependent on the teacher, but they will be able to make their thinking more visible by embarking on an independent learning experience. Teachers at institutions like colleges and universities are responsible to prepare scaffolds of a knowledge framework instead of encouraging rote learning. As a result, students will have a better connection with their learning experience hence the concepts they are ought to learn. Their thoughts are seen as deriving from actions; actions are internalized, or carried out mentally in the imagination, and this way thinking develops (Piaget, 1963).

Therefore, it can be concluded that the purpose of developing the POL: PLL & PLR is not merely to help students to pass their chemistry examinations, but it also gives a much more meaningful purpose; developing independent learning skills. Hopefully, this research is able to help other chemistry as well as STEM teachers to develop instructional strategies that forge meaningful learning.

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Conflict of Interests

The author declare no conflict of interest in this study.

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