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Students' Perceptions of the Use of Collaborative Writing and Peer Reviewing in Wiki Laboratory Reports

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Abstract

Laboratory reports are synonymous with laboratory sessions in undergraduate chemistry courses. This research restructures the format of laboratory reports, to avoid repetitive churning of laboratory reports that accompany weekly experiments that do not create avenues for proper appreciation of the scientific essence of the experiment. This research explores the dual use of wikis and peer-review technique that rely on students' collaborative efforts to improve scientific literacy. Student perceptions are captured upon implementation and valuable findings are shared. Collaborativeness among students surfaced in the interview findings and aspects of having more reflectiveness, critical-thinking and research skills were present as values for the peer-review activity. While the research explores the presentation of l laboratory reports in chemistry, the peer-review technique can be extended to courses that involves the assessment of student writing. The research findings showed how constructive alignment between the task, assessment and learning outcomes is necessary to ensure that learning gains from peer-reviewing are achieved. Also noticeable was that proper technological and pedagogical considerations are necessary in the planning of tasks.

Keywords: *collaboration, laboratory report, peer-review technique, scientific writing, student perceptions*

1. Introduction

Learning in the laboratory forms a very important aspect of learning in most science courses. Core chemistry courses, such as general chemistry, organic chemistry, and higher-level chemistry, usually incorporate laboratory work that emphasises hands-on skills. Within the laboratory environment, students actively learn through inquiry-based experiments while also gaining experiences and skills that are related to scientific practices (Auchincloss et al., 2014; Evans et al., 2016; Hunter et al., 2007; Szteinberg & Weaver, 2013; Yore et al., 2008) such as specific technical techniques, critical thinking, scientific literacy, and data analysis methods (Dood et al., 2018). Given the vast array of skills students can acquire from laboratory sessions, various assessments can be developed to assess students' learning from these sessions. Two ways of assessing students are by evaluating psychomotor abilities and by evaluating cognitive abilities. Psychomotor assessments involve assessment of specific in-situ technical skills and the relevant competencies required as outlined under the procedures of the experiments, while an assessment of cognitive ability involves assessing how students reason and demonstrate understanding of the results obtained. Such presentation of results adopts scientific reporting formats.

A long-standing practice in assessing students' cognitive abilities is through laboratory reports. Laboratory reports communicate observations, organise data and workflow, allow visualising of patterns and relationships, and clarify thought processes (Green et al., 2017). The goals of preparing a laboratory report are to demonstrate thinking scientifically (Deiner et al., 2012) and to prepare students to act, think, and reason as authentically as possible in comparison to the practices of real-world scientists (Lerner, 2007; Russell, 2002). Notably, writing is a complex skill and requires sustained, reiterative support rather than a single one-off experience (Brownell et al., 2014) and is most significantly impactful when there is knowledge "transfer" in ways that students can connect the dots between ideas and benefit from divergent learning experiences (National Research Council, 1999).

Typically, expository (traditional) approaches are used in the teaching laboratory with recipe-style protocols where students follow a predetermined set of procedures for data analysis. While this method allows learners with opportunities to develop practical skills such as using the apparatus, mixing solutions, setting up experiments, and even meeting the required objectives of the laboratory session, this teacher-centred approach leaves very little room for thought or reflection of the concepts that underpin the experiment (Quattrucci, 2018). O' Dennell (2014) points out that students can even complete a laboratory report fairly well without a strong grasp of the theories behind the experiment. As a result, the work submitted may not be a true reflection of the students' ability and understanding of the knowledge that is reported. Another point to note is that individually composing laboratory reports results in a voluminous amount of laboratory reports every week. As such, a shift of the centre of gravity to one that progressively improves scientific literacy and at the same time manages grading workload will be beneficial to students and instructors.

2. Literature Review

2.1. Wiki as a Tool for Scientific Reporting

Wiki, a Web 2.0 software, allows users to create and edit Web pages. Content can be changed, removed, edited, and added and this task can be shared between several users. Closest to the present research is the studies by researchers who have used Electronic Laboratory Notebooks (ELN) (Lawrie, 2016; Bromfield Lee, 2018) and CHEM-wiki (Elliot & Fraiman, 2010), where students collaboratively prepare laboratory reports using the wiki software. Aspects highlighted in this research is the collaborative nature of preparing laboratory reports otherwise absent in traditional laboratory reports. Presenting laboratory reports in an electronic format has enabled students' sharing of ideas and the flexibility to link external references (Elliot & Fraiman, 2010); it is a more environmentally friendly method and students can share images and discuss how to accomplish certain tasks (Bromfield, 2018). Moreover, it encourages student ownership and appraisal of good or bad data because data is being presented for a wider audience rather than for individual submissions of reports (Lawrie, 2016).

2.2. Peer Feedback

Peer feedback is an approach aimed at involving students in the assessment of learning by offering opinions, suggestions, and comments on the work of other students. Through the process of critically evaluating good and poor-quality work, students learn to take ownership of their own work. When peers read and evaluate content created by others in the class, this would mean that the work created has to be of an acceptable quality since critical reading and writing are involved. Pedagogically speaking, these functions extend insights into students' cognitive processes and this allows the instructor to identify specific areas that require further support among students (Lawrie, 2016). Thus, in addition to using the wiki to recreate laboratory reports, peer-reviewing technique can also be incorporated to involve students in the assessment of work quality.

Students' metacognitive skills benefit when peer-reviewing is incorporated. Notable benefits of peer-reviewing in scientific writing are improved ability of students to select literature relevant to the matter under study, thoroughly understanding the specific requirements of the components of a scientific paper, improved ability to critique a scientific paper (Rangachari & Mierson, 1995; Seals & Tanaka, 2000;

Subramaniam, 2010; Yankulov & Couto, 2012), alongside minimisation of common writing errors and inaccurate reporting (Colthorpe et al., 2014). Besides, students acquire improved confidence, motivation, and independence in writing (Romulo et al., 2018). Dominating the discussions of peer reviewing is the inclusion of formative assessments that have contributed to greater student learning. Formative assessments have countered limitations of the usual summative feedback given by instructors (Sims, 1989) which often result in a grade deduction before students are allowed to remedy mistakes.

While there is a general consensus that peer-reviewing is beneficial to student learning, some researchers have highlighted otherwise. Ge (2012) surveyed engineering students and found that students preferred to use a word processing software to present their work rather than Wikis. Issues that were reported were difficulties deciphering work posted by their peers, wikis were a less organised option, and creating wikis was time-consuming. In two separate studies, Coyle (2007) and Leung et al. (2009) raised the question of whether wikis are truly suitable for measuring collaboration among students. Unless required, students will not voluntarily edit their peers' work (Coyle, 2007). This defeats the aim of prompting collaboration among students. Similarly, Leung et al. (2009) analysed quantitative and qualitative results from a Media wiki project and found that very limited collaboration occurred between group members in the Wiki learning environment. Such findings point to the need for assessment criteria when using the wiki and raise questions about whether it is possible to assess collaboration in the wiki writing process. Kaufmann and Schunn (2010) found that students had concerns about the fairness and accuracy of peer assessment (i.e., unqualified peer reviewers) especially in cases where instructors do not moderate the marks provided by peer reviewers. Strategies that have been recommended to improve the quality of peer feedback can be summarised as increasing students' peer assessment experience (Sluijsmans et al., 2001; Wen & Tsai 2006); specifying the criteria for peer assessments (Falchikov & Goldfinch, 2000; Smith et al., 2002); and supporting students with proper training and practice in peer assessments (Cheng & Warren, 1997; Falchikov & Goldfinch, 2000).

3. Research Method

3.1. Research Novelty

The conflicting findings and suggestions to improve the implementation of peer-reviewing indicate a need for further research. The novelty of the present research is in addressing previously reported shortcomings via the research design. Therefore, several new pedagogical approaches were incorporated. The present research is angled to firstly, specify students' role in contributing and reviewing the laboratory wiki (thus addressing the issue of voluntarily participation and no participation); and secondly, to incorporate instructor assessment of from peer-reviewers comments using the same rubric provided to the students (this is to address unqualified, sporadic and the inaccurate peer-review comments). Also included were several rounds of practice to ensure students are familiar with the workarounds of the wiki and requirements of reviewing comments. The present research is aimed at capturing students' experiences in the context of a chemistry course; and exploring the following research questions:

i. What were the students' experiences in laboratory work reporting?
ii. What were the challenges in writing laboratory wikis?
iii. What did the students think of the peer-reviewing elements?

3.2. Design Overview

Traditionally laboratory reports were written individually and students would submit their laboratory reports online or through hard copy. In this module, two alterations were made. First, students work in groups to create a laboratory report. Second, the use of word-processing documents to produce laboratory reports was replaced with a collaborative tool called "Wiki" available in the students' learning management system called Blackboard. Students were divided into groups at the beginning of the semester by the instructor. For each group of four students, two of the students would create the laboratory report and the other two would review the laboratory wiki. The students who created the laboratory wiki were designated as "contributors" and students who reviewed the laboratory wiki were called "reviewers". The laboratory wiki followed the usual format of title, aims, results and questions,

conclusion, and discussion. The tasks of the two contributors were divided into two: one student prepared the aim, results, and conclusion and the other would prepare the title and discussion. The contributors were given 48 hours to create the laboratory report upon completion of their laboratory practical. After 48 hours, the group of students in charge of reviewing the laboratory report would then evaluate their peers' work, with 48 hours to complete their reviews. The contributors would post their work using black font and the reviewers would post their work using the blue font.

Student roles were rotated in two ways: 1) between contributing (to the laboratory wiki) and reviewing (the laboratory wiki) different components of the experiment and 2) between their roles as contributors and reviewers. Regarding the first rotation, the rationale behind assigning one student to complete the aim, results, and conclusion and the other to complete the title and discussion is because these components require different reporting skills as such, rotating the roles allows students to learn the different skill sets pivotal to each component. For example, when completing the "results" component, students learn to create graphs, work out calculations and analyse data using various tools so that a conclusion can be drawn from the raw data obtained from the laboratory. Comparatively, to complete the "discussion" portion of the laboratory wiki, students are required to reason and link the data obtained from the "results" section to theoretical concepts in chemistry. To do this, students are required to research and select relevant concepts, analyse these concepts for their appropriateness and then reword these concepts to tie them into the context of the experiment. To ensure fairness of workload among students in proportion to the assigned assessment for each laboratory report (each laboratory report contributes 1% of their overall score), students are only expected to only contribute or review an assigned component of the laboratory report. This is to upkeep student motivation, by ensuring that students' efforts are commensurate to the scores assigned (which is only 1% for each laboratory wiki). Moreover, by contributing a portion of the laboratory wiki, students are encouraged to prioritise the quality of their contribution. Another element in maintaining the integrity of the task, is to ensure students of a group are not allowed to view laboratory wikis of students from other groups. This prevents students from copying the content from other groups.

For the second rotation, the reasons for swapping between contributing and reviewing are explained. After the "contributors" have completed their work, the "reviewers" reviewed the laboratory wiki, adding their comments using a different colour font. The "reviewers" reviewed the "contributors" work and assessed the consistency, accuracy, and correctness of the information posted, guided by a common rubric. Should the "contributors" fail to provide sufficient information or miss portion(s) or post incorrect answers in the laboratory wiki, the "reviewers" should complete or correct these sections. The reviewers would have had the same laboratory experiences as the contributors so there is common ground for the reviewers to fully understand the context of the laboratory wiki. For "discussions" where the "contributors" had already elaborated on the concepts, the reviewer can either choose to deepen the contributor's work by adding new information, reflecting on aspects that were written, or extend on how the discussion points can relate to real-life applications. It was imperative to ensure that the reviewers were aware of their duties to ensure that a critical review was posted, rather than merely agreeing with the "contributors" work. In such instances, it was made clear that no marks would be awarded if the "reviewer" merely paraphrased what the "contributors" had written. A good show of reflectiveness, critical thinking, and extension of knowledge would earn them a higher score on the point scale. This point was emphasised during the introductory presentation for student and captured in the rubric shared with students.

3.3. Preparations

During the first week of the semester, students were informed of 1) their roles as "contributors" and "reviewers" (See Table 1), 2) location of the relevant documents on their learning management system (in this case Blackboard), 3) pertinent due dates for "contributors" and "reviewers", 4) requirements of a good write up for each laboratory component (i.e., aim, results, discussion, and conclusion), 5) good and poor examples of past student work, and 6) a rubric outlining categories and mark distribution. The above information was presented in a 60-minute session and the instructors clarified all questions that the students had. To reassure students that allowances would be given for the learning curve ahead when preparing the laboratory wikis, leeway was provided for the first two experiments. Instead of starting with

summative assessments, formative feedback was provided to all students to understand how to properly contribute and review laboratory wikis. Summative assessment started for laboratory wikis for the third experiment.

3.4. Instructor Assessment of Laboratory Wikis

The grading of laboratory wikis was done by the instructor after the reviewers had completed their reviews. The instructor assessed the contribution of each group member. This general method of assessment was to ensure students had contributed personally to the wiki and that their classmates were not commenting on their behalf. Wikis from the Learning Management System allow very accurate tracking of number of words and edits made (see Figure 1) and thus was selected as a tool for this activity as opposed to other platforms. Integrated into the learning management system are Course Analytics, Course Reports, and Turnitin plagiarism detections and instructor grading was done using a set rubric that allowed direct grade calculations of the portions that was evaluated. Instructor feedback was given by inserting direct comments on the laboratory wiki page. The instructor's feedback was inserted under each section of the laboratory wikis (i.e., aim, results). The instructor commented in red to contrast against the contributors' black font and reviewer's blue font in the laboratory wikis. Grades were awarded based on the rubrics that were shared with students; these grades and rubrics were visible to students throughout the semester.

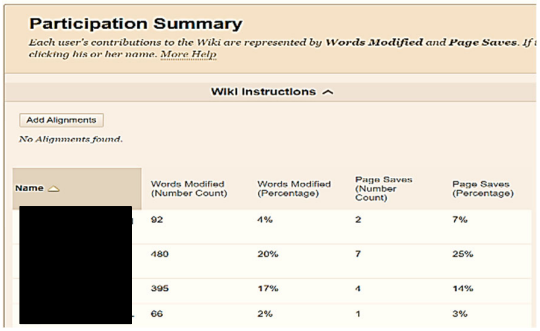

Figure 1. A screenshot of student participation summary

Table 1. An Example of Laboratory Wiki Task Distribution.

Contributors for Aim/Results/Calculation/Questions/Conclusion	7, 10	9	8	2	7, 10	9	8
Reviewers for Title/Discussion	2	7, 10	9	8	2	7, 10	9
Contributors for Title/Discussion	8	2	7, 10	9	8	2	7, 10
Reviewer for Aim/Results/Calculation/Questions/Conclusion	9	8	2	7, 10	9	8	2

Note: The number(s) in the boxes correspond to the laboratory experiments: i.e., 9 = Experiment 9.

3.5. Research Design

The study employed a qualitative research design. The participants were interviewed using open-ended questions. A semi-structured interview approach was adopted. The interviews were conducted face-to-face. The interviews were recorded, transcribed, and translated for analysis. The participants signed a consent form and were assured of privacy, confidentiality, and anonymity. Out of the eight students enrolled in Section A of a General Chemistry course, seven volunteered for online interviews which were recorded and transcribed for thematic analysis. General Chemistry, CHM151, is a first-year chemistry course offered in an American Degree Transfer Programme taught at a private higher education institution in the Klang Valley, Malaysia. Students require a pre-requisite chemistry course before enrolling into CHM151. Relevant information of participants is shown in Table 2.

Table 2. Participant information

Participants	Gender	Abbreviation	Semester
Student 1	Female	StuF	3
Student 2	Male	StuA	2
Student 3	Male	StuY	3
Student 4	Female	StuJ	4
Student 5	Male	StuS	5
Student 6	Male	StuYS	4
Student 7	Female	StuZ	2

4. Findings

4.1. Findings for the First Research Question

In relation to the first research question of "What were the students' experiences in laboratory work reporting?" three themes emerged. The themes are 1) Prior Experiences; 2) Mixed Initial Reactions to Laboratory Wikis and 3) Division and Management of Tasks.

4.1.1. Prior Experiences

StuS mentioned that he had to hand in hard copies for his previous laboratory reports and he described printing his laboratory reports as a "hassle", having to always visit the printing shop. All the other students also revealed that they submitted hard copies of their laboratory reports. StuZ mentioned that she took about thirty minutes to an hour to complete her laboratory report to which, upon submission, her instructor discussed the results with everyone. StuA wrote his laboratory results in a laboratory manual, which was then submitted for grading. StuY explained that in his secondary school the teacher guided them on how to write the laboratory results and provided examples. He described his current experience of having to write reports from scratch as "very hard, because it's new". It was revealed the students had never worked collaboratively to prepare a laboratory report in their previous chemistry classes.

4.1.2. Mixed Initial Reactions to Laboratory Wikis

From the seven students that were interviewed, it was noticed the students had mixed reactions to the prospect of using wikis in presenting their laboratory work. StuYS described his initial reaction as "a lot easier as there is division of work", and StuS added what came to his mind was that there was no need to print and described working on wikis as a "go green" initiative. StuZ mentioned that it "feels new because never tried writing a laboratory report online with a deadline of two days" while what struck StuJ first was that she thought it would be "confusing as reviewing could create conflict" as she needed to "correct other students' work". StuA was "a bit puzzled as I had never experienced it before" while StuY described it as "not quite hard" whereas StuF welcomed the change as there was no more printing required. Generally, the seven students reported a range of initial reactions, and it was found that only StuZ was familiar with using Wikis as she had used it in a previous course. The remaining students expressed that collaborative writing and using the wiki was new to them.

4.1.3. Division and Management of Task

It was revealed that the students approached their assigned duties differently. Some of them explained that they created WhatsApp groups among themselves to divide tasks and communicated through WhatsApp messages (i.e., StuYS, StuS, StuA, and StuZ) while some directly contributed to the wiki page without prior discussion and explained that "it depends on who did it first, the first person does their part followed by the next …it is more like first come first serve basis" (StuJ). Similarly, StuF mentioned that work was done on a "voluntary basis" with the last person picking up what was left and completing it. StuZ mentioned that among her group of students, the WhatsApp group was used to exchange opinions,

especially when her classmates made mistakes, and to "discuss what is wrong". She shared on one occasion she received a WhatsApp message the informed her that her posting of the unit of Molarity was incorrect – "it should be mol/litre but I wrote mol/militre" which she corrected.

4.2. Findings for the Second Research Question

In relation to the second research question of "What were the challenges in writing laboratory wikis?", one theme emerged – Technical Difficulties.

4.2.1. Technical Difficulties

The wiki tool that was used in this module did not permit simultaneous editing by students. As such, almost all students raised this as a challenge. When there were concurrent usage of the wiki page, their work would be lost. This created challenges for students as their work was not saved. YS expressed frustration and shared that when it first occurred, he was discouraged and subsequently (as a measure to safeguard his work) created his work on an MS Word document before posting it on to the wiki page. YS added that a "read-only" version of the wiki page indicated that another student was posting their work. StuZ mentioned the "fail to edit wiki page" notification means all "your hard work is gone and had to restart everything again". She too resorted to backing up her work in MS Word. She elaborated that writing chemical formulas was challenging as the use of subscript required her to repeatedly scroll up to the function bar. She wished that there was a hotkey function for the wiki page for the subscript function. The same difficulty was echoed by StuF, StuY and StuA, mentioning that after knowing only one person can edit at any one time, they had to start early because typically heavy usage of the wiki is common during the hours before the deadline. StuA explained that he primed his work on MS Word and MS Excel (for graphs and tables) before using the "insert image" function to post his graphs on to the wiki page.

4.3. Findings for the Third Research Question

Regarding the third research question of "What are the students' perspectives of the peer-reviewing element?" two themes emerged. They are 1) Being a Contributor vs Being a Reviewer and 2) Advantages and Disadvantages of Peer Reviewing.

4.3.1. Being a Contributor Vs Being a Reviewer

The students explained how their perceptions of the roles of contributing to and reviewing text on the wiki page differed. For the contributor's role, the students mentioned that:

StuS – "…being a contributor is easier than being a reviewer"
StuZ – "I think both roles are equal but the reviewers' scope will depend if the contributor did a good job"
StuJ – "I had a fun time doing it... but I was also very scared that I might do a mistake which will be corrected by the reviewer. That forced me to do better… check my work"
StuA – "...being a contributor is difficult because when I'm the contributor sometimes I don't have any idea on how to do it… how to start… and will normally discuss with my friend or refer to other groups for ideas".

For the reviewer's role, the students mentioned that:

StuS – "When you say you look at contributors' work you got to figure out why ... had to research a lot a lot a lot... make sure you know your stuff. As a reviewer, you must be right, there's no chance for you to be wrong. The review part especially, makes me think actually. I've written both types, paper and wiki. The paper requires less thinking other than the calculation and discussion part. Whatever results you have you just paste it in Microsoft Word but in wiki, when you review there are better connections with the laboratory experiment."

StuF – "Harder for reviewer, I think. Because we need to explain…they (contributors) already give a point…if their point is valid, then you have to find another point to support that point…. compared to contributors, who already give the point which sometimes is accurate and sometimes not that accurate... so we (reviewers) need to justify."

StuA – "I think reviewing is easier because…let's say we are reviewing the calculations… if I'm the contributor, I think I won't have idea on how to do it… but if I'm reviewing it, I can look, I know I can look at his procedures and then maybe I can find the errors inside…at least I have an idea."

StuY – "For me I think reviewing is harder because …we need to explain what is written by the Contributors…if not we will not get marks."

StuYS – "When you're reviewing, you should write it in a correct way. And then compliment them if they do something right."

Various perceptions of being a contributor and reviewer came to light. It can be said that the students were more conscious when they posted in the wikis as they were aware that their postings were being read by their peers. This awareness made them more conscientious in their postings. To ensure the correctness of the information, the students revealed that they had to do more than usual research as getting their facts right was imperative. Between the role of being a contributor or reviewers, both roles seem to measure up in levels of difficulty. However, what was distinctly mentioned about reviewing is that having to reason what was written by the contributors made the task more challenging as more figuring-out was required and here, the students cited the requirement stated in the assessment rubric, of having to reason what was written by the contributor.

4.3.2. Advantages and Disadvantages of Peer Reviewing

When asked about the advantages and disadvantages of writing on laboratory wikis and the elements of peer reviewing, the students shed light on multiple aspects. The students had varied ideas and comments about what struck them as being advantageous and disadvantageous. Several subthemes emerged from the students' responses.

4.3.2.1. Utilizing the Reviews Provided

Three students (StuS, StuA and StuF) brought up the positive aspects of the feedback extended by the reviewers on the wiki page. StuS mentioned that the feedback made him "learn from these mistakes". StuA brought up how he learnt the importance of the subscript function in writing chemical formulas and how to report using correct significant figures. StuA also mentioned he learned how to properly conclude an experiment and mentioned that "I realised that the conclusion is based on the aim of the experiment after reading feedback from my reviewer". StuF highlighted that when she was unsure of how to contribute to parts of the wiki page, she would refer to previous wikis where the "good work" feedback was inserted by the instructor and positive reviews were mentioned and replicate the same approach for other laboratory wikis.

4.3.2.2. Task Distribution

To the aspect of dividing the laboratory wiki into several parts to be completed by students, both advantages and disadvantages were noticed. The advantages were highlighted by StuZ. She mentioned that by "reading the contributors portion, that clarified the lecture concepts further…it helped me figure out some missing parts... and when you do the entire laboratory reporting on your own, it creates a lot of pressure but when doing small portions, I understand it better". StuY favoured distributing the workload to make it manageable and mentioned that "either we learn the calculation through completing the results portion or we write about the concepts in the discussion, smaller tasks make it more manageable." On the contrary, StuYS disagreed and mentioned that by dividing the laboratory report among students he only focuses on the part that is assigned to him and he may be missing out on learning how to perform or complete calculations that is commonly done in the 'results and calculation' portion.

4.3.2.3. Online format

Regarding switching to online submission for laboratory wikis, StuS mentioned that completing reporting online is in tune with all other conversions of going paperless. StuS added that with the wiki being online, he is able to access it anywhere when he is logged into Blackboard. However, StuZ pointed out that writing the chemical formulas by hand is "faster" than having to scroll up and down to access the subscript button. To her, that was time consuming. A comment was made by StuJ that she wished the wiki would have a notification reminder to remind her and her group mates of the due dates. She mentioned that the onus of reminding her classmates to meet the due dates had to be taken up by some classmates to make the writing process smooth and quipped "we are constantly chasing the procrastinators".

4.3.2.4. Favourite Component of the Laboratory Wiki

StuS mentioned that he looked forward to manipulating the data obtained in the laboratory and presenting it in the "results and calculation" section as this ultimately is where the satisfaction lies. Whereas the reviewer role makes him think and he adds "I can't copy stuff from the laboratory manual because I have to have the knowledge and rephrase it to make it relevant". StuZ mentioned that the writing and reviewing "discussions" are beneficial to link the theory to numbers while writing and reviewing "results and calculations" are beneficial to her to do well in her assessments. StuYS provided an example and mentioned that the discussion is "the flow of the experiment…like for example, Hess's Law…why it happens, how it happens, I can make a connection to what I study in class when I write about it in the discussions".

5. Discussion

This research noticed good student participation in the writing and reviewing of the laboratory wiki reports. Especially noteworthy is student engagement in the peer-reviewing process, which was not left to voluntary student participation but was pre-set by the instructor. This eliminated student absences in reviewing and editing their peers' work, which would have hindered the learning gains that accompany the peer-reviewing activities. Coyle (2007) mentioned unless required, students will not volunteer to engage in peer-review. The present research also revealed that the in completing the peer-reviewing activity, students were required to reflect on their peers' wiki posting and explain the relevancy of the points raised by their peers. Illana-Mahiques (2021) mentioned that there is an impact of audience awareness on a students' own writing and this element was seen when StuJ mentioned that she had to check her work before posting to avoid her work being corrected by the reviewer. StuS mentioned that he "learned from his mistakes", while StuA mentioned that he learned how to properly compose the aim of an experiment "after reading feedback from my reviewer". Cho and MacArthur (2010) termed this aspect as learning-by-reviewing hypothesis, which explains that students' own writing skills may improve because of the engaging in peer review. Another aspect that was demonstrated by the students (e.g., StuS, StuA and StuF) is that the reviews were beneficial to them. This addressed concerns of the value of the reviews in terms of accuracy and fairness that was previously highlighted by Kaufmann and Schunn (2010). Student responses implied that the quality of contribution (either by contributor or reviewer) was meaningful to them, thus eliminating concerns of comments being sporadic, inaccurate and not meaningful.

The role of reviewing was often described as challenging and requiring extended research. StuS mentioned the need to have to "figure out why" and "had to research a lot"; this was echoed by StuF, who mentioned that reviewing requires the need to support or justify what is already posted. The evidence that emerged in the present research is consistent with the assertion by Illana-Mahiques (2021) that reviewing develops critical evaluation skills, identifies gaps in argument and detects inconsistencies in structure.

However, on the aspect of collaboration, the present research found that the collaboration was uneven throughout the writing process. While only a handful of students shared that they were collaborating with their classmates throughout the writing process, substantial evidence points that collaborative work was

apparent in the early stages and also present were findings that indicate some students were willing to commence work on the laboratory wikis without informing their peers, consequently leaving their classmates to patch up what had not been done. Perhaps the task design limited interaction opportunities among students. Aydin and Yildiz (2014) highlighted that the type of task does lend a role in affecting learner interaction in wiki-based writing studies. Compounding this notion are findings from other researchers (Pica et al., 1993; Robinson, 2001; Skehan, 1996), who concur that type of task affects collaboration even in non-technology supported collaborative writing. Similar detection of partial and early collaborative efforts was also reported by Hsu and Lo (2018), where beyond the outlining stage of the wiki-mediated writing activity, student collaboration was not evident. This opens up worthy areas for future research in the creation of new pedagogic strategies that can encourage non-assessable collaborative behaviours.

Up until this study, it was found that the students interviewed were new to using wikis to prepare laboratory reports. The students, however, had a good understanding of what a laboratory report is and did not bring up issues with having to learn how to write a laboratory report. This could be attributed to the students possessing prior knowledge of writing laboratory reports. However, the wiki tool used in this study was considered not user-friendly as it crashed when students were simultaneously editing the wiki and is not suited for technical writing (i.e., having to write chemical formulas or creating graphs). A study by Berthoud and Gliddon (2018), which used wikis for engineering students' Capstone projects, reported similar negative experiences of the wiki being unsuitable for uploading images and spreadsheets. In contrast, a positive experience was reported for an English Composition course, whereby the researchers did not encounter issues when wiki-mediated collaborative writing was used in an English composition course (Hsu & Lo, 2018). This points to a weakness in the present study, where the wiki tool may be beneficial for collaborative work but not if simultaneous editing and collaborative work are required. While the wiki has shown strength in supporting, tracking, and even displaying analytics of student participation when writing collaboratively (Berhtoud & Gliddon, 2018), the use of the wiki in the present research hit a stumbling block as it required students to concurrently edit the wiki. The students were resourceful in devising alternative avenues to overcome technical issues; however, future work that requires collaboration and concurrent editing for a technical course should aim to use a different medium.

6. Conclusion

Learning from past research on the incorporation of collaborative writing in laboratory reports, the obligation of students with the need to review their peer's work indeed overcame challenges of voluntary reviewing. Various experiences were captured throughout the laboratory wiki writing phases; from students' initial reactions to students rationalizing the advantageous and disadvantages of their experiences. It is absolutely pivotal that students can create, communicate, collaborate, and critically appraise not only their own technical writing but what they read too. Incorporating peer-reviewing elements created mindful habits of writing and reading other students' work, shoring up benefits to students' scientific literacy. Critical reading and writing is otherwise taken for granted when only preparing reports for a single audience – the instructor. As indicated by the findings, when peer-reviewing contributes to students' assessment, the formative aspects of critical thinking begin to emerge. The use of peer-reviewing techniques, should be approached with caution and scaffolded carefully, for the actual benefits to precipitate, as the present and past research has suggested. Unlike the significant evidences that captured the peer-reviewing aspects in the present research, collaborativeness was not measured or assessed in the present research and therefore was not inherently present among all groups of students. What was clearly present was cooperative learning where students accomplish small tasks or portions to create a final product. In totality, the present research offered valuable insights into the structure, utilization, student perception and limitations of the module design.

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