Enhancing Self-Directed Learning Skills via Blended Problem-based Learning in Chemistry Learning

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Abstract

Students' mastery of the Three Representation Levels of Chemistry Concept (macroscopic, microscopic, and symbolic) is still weak and this has affected their academic performance in Chemistry subject. This has resulted from the poor engagement of students in the teaching and learning process. The current teaching practice is teacher-centered learning and does not encourage self-directed learning. Therefore, there is a need to implement Blended Problem-Based Learning (BPBL) which encourages students' self-directed learning in face-to-face and online learning mode. This study is aimed at: (i) identifying how self-directed learning skills are being applied in the BPBL, and (ii) identifying how BPBL enhances Chemistry learning. This study employed a qualitative approach through a case study research design (exploratory and explanatory). Two teachers and 20 students were selected using purposive sampling, which became the sample for this study. Data were collected from observations, students' documents, and

semi-structured interviews and analysed thematically. Generally, the findings indicated that the BPBL approach was able to enhance students' ability to: (i) plan a problem-solving process, (ii) analyze, assess understanding and provide justification as well as (iii) evaluate references and information. These skills have contributed to mastery of the Three Representation Levels of Chemistry Concept and they were able to avoid the formation of alternative concepts. The findings of this study can serve as a reference to effectively implement BPBL in the context of Chemistry learning in Malaysia.

Keywords: *Three* Representation Levels of Chemistry Concept, Blended Problem-Based Learning, Self-Directed Learning

Introduction

The current teaching practice in most Malaysian schools is still teacher centred [1, 2]. This leads to poor involvement of students in the teaching and learning process. Previous studies have identified that the teacher-centred classroom is a hindrance to mastery of scientific concepts and higher-order thinking skills, especially in Chemistry subjects [3-7]. One of the problems typically faced by Malaysian students in this subject is mastery of three levels of Chemistry representations: macroscopic, microscopic, and symbolic [6, 8, 9]. Misconceptions or known as alternative concept formation is developed when students memorize and passively accept the information without a deeper investigation [10]. Thus, a teaching strategy that focuses on encouraging students' active participation is highly needed to help them to explore and construct their understanding with minimal guidance from their teachers.

Problem-based learning (PBL) is found effective in ensuring students are capable of constructing and conducting their learning, and developing a deeper understanding of this concept [11, 12]. This can be achieved as one of the main emphases is developing students' self-directed learning skills. This means that students are able to assimilate and accommodate their schemata [13] to develop an understanding of a particular concept in Chemistry learning.

In enhancing the outcomes of PBL, integration of technology is needed. This is to reduce the dependency on the teacher as a knowledge provider and to encourage self-directed learning [14, 15]. Also, the integration of online learning in PBL, known as Blended Problem-based Learning (BPBL) is vital to extend students' exploration and understanding [4].

Previous studies such as Ibrahim et al., and Abubakar and Arshad [4, 16] view self-directed learning as learning activities that are either conducted individually or with the help of peers. These activities occurred at every phase of the PBL. Since self-directed learning is deemed to be important to enhance students' mastery, it is therefore important to critically identify how these skills are being applied in the BPBL lessons. With the integration of both face-to-face and online learning platforms, the application of these skills might be different compared to the traditional PBL. Hence, this study is aimed at:(i) identifying how self-directed learning skills are being applied in the BPBL, and (ii) identifying how BPBL enhances Chemistry learning. The following research questions are set for this research:

1. How are self-directed learning skills being applied in the BPBL?
2. How does BPBL enhance Chemistry learning?

Literature Review

Blended problem-based learning (BPBL)

The Blended Problem-Based Learning (BPBL) approach is a traditional PBL approach that combines face-to-face and online learning modes [15, 17]. Accordingly, BPBL is an active learning approach that emphasizes three main characteristics namely: (i) student-centered learning; (ii) problem given is real-life oriented, unstructured, and has multiple solutions; and (iii) the learning process involves self-directed learning and collaborative learning process [18, 19]. This learning approach was pioneered by several cognitive and constructivist experts including [20]. Vygotsky emphasizes the construction of knowledge from students' experiences and interactions with the environment [20]. Students' interaction with the environment refers to the social interaction between a teacher with the student (teacher-students) and student with the student (students). Through social interaction, students can reach the Zone of Proximal Development (ZPD) which is the distance between students' mental development in solving problems alone compared to students' mental development when solving problems with the help (Scaffolding) from teachers or friends [20]. Previous studies have shown that the combination of face-to-face and online learning modes is an ideal learning approach that can highlight the advantages and at the same time balance the disadvantages of the two learning modes [21].

Among the advantages of online learning is that it can overcome monitoring problems [15]. In Malaysia, commonly, the number of students in a class is large [1, 22, 23]. This situation complicates the implementation of PBL and is contrary to the original concept of PBL which only involves a small group of students which consists of only 4-5 students [24]. However, this problem has the potential to be solved through online learning modes such as the usage of discussion platforms that allow teachers to monitor large numbers of students simultaneously. It also has the potential to enhance the student learning process through discussions that involve not only a group of students but also the whole class [9, 25, 26].

In addition, discussions involving asynchronous discussion forums also allocate time for students to express opinions and ideas [27-29]. This allocation of time provides sufficient time for students to analyze, evaluate and provide justification related to a discussed content learning. In addition, the integration of the online learning mode offers information from various sources without the restriction of place and time [30]. This allows students to explore information according to their preferences. Students can also analyse and evaluate information shared by other students [31, 32]. This situation can emphasize the process of self-directed learning and collaborative learning.

The BPBL Strategy

BPBL strategy was developed by adapting the PBM model by Hmelo-Silver and Ferrari [18] as in Figure 1. This strategy consists of 4 phases namely (i) problem scenario, (ii) solution for the learning issue, (iii) problem follow-up and presentation, and lastly (iv) reflection. In phase 1, students are required to form small groups in turn assigning tasks to each group member. There are four main roles of each group member namely: (i) group leader, (ii) secretary, (iii) recorder, and (iv) observer. Next, each group was given a problem to solve. There are two problems given to students namely (i) toothache and (ii) water pollution. In problem 1 (toothache), in the problem scenario phase, students analyse the problem and identify the facts, ideas, issues, and learning actions, and list them into a table known as the FILA chart (fact, idea, learning issue, and action) as in Table 1. This

FILA chart is a thinking tool in helping the student to organize their thinking in solving the problem [18, 19, 33]. In contrast to problem 1, in problem 2 (air pollution), students must first arrange the order of the learning process and also determine the thinking tool to be used (students are free to use FILA chart as in problem 1 or another thinking tool). This difference plays a role in looking at the ability of students to carry out a self-directed learning process in problem 2 after going through the BPBL learning process in problem 1.

Next, students complete the FILA chart (problem 1) and the thinking tool (problem 2), then upload it into the online discussion forum. In contrast to the previous step, the student discussion is not limited to group members only but involves the whole group [4, 14]. This situation has the potential to improve the skills of analysing and re-evaluating the learning facts, learning ideas, learning issues, and learning actions that have been set by each group, as well as the potential to improve the process of self-directed learning [2]. Then, students improve their thinking tool content based on feedback from the other group and re-upload the thinking tool, known as FILA chart 2 (problem 1) and thinking tool 2 (problem 2). In the next phase, which is the solution for the learning issue phase, students distribute learning issues among group members to be resolved. Through the implementation of BPBL, students have the opportunity to obtain information from any source, especially from the Internet [2]. Students have to get the information only from reliable sources to ensure the accuracy of the information obtained [7, 34]. Once students have solved each learning issue, they presented the solution of their respective learning issues between group members. After getting the best solution to the given problem, each group presents their findings in front of the class. At this phase, students need to assess the understanding of other peers in relation to the solution of the problem presented. In addition, they also need to justify each question asked by other students. Lastly, students conduct a reflection on the problem-solving process they have gone through. This reflection is carried out to ensure the students can apply the learning process to other problems and subsequently improve the weaknesses of the problem-solving process passed [2, 4, 14].

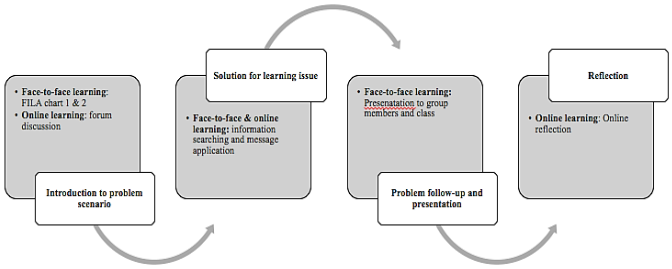


Figure 1: BPBL Strategy

Self-directed learning skills in BPBL

Self-directed learning is one of the most important processes in BPBL. Kiili et al., and Karatas and Arpaci [34, 35] defines self-directed learning as a process in which individuals take initiative either alone or with the help of peers in (i) diagnosing learning needs; (ii) setting learning goals; (iii) identify sources of reference materials; (iv) select and implement appropriate learning strategies and (v) evaluate learning outcomes. The concept of self-directed learning has been detailed by Hmelo-Silver and Ferrari [18] and other scholars [19, 31, 33] through the PBL approach which involves five constructs namely (i) using existing knowledge in analysing problems, (ii) formulating learning issues, (iii) plan and implement plans in solving learning issues and (iv) apply new knowledge to

problem-solving and (v) reflect on the learning process of problems that have been passed.

Ibrahim et al. [14] has adapted five constructs of the self-directed learning process in BPBL [18, 19, 33]. He combined the construct of identifying the lack of existing knowledge and formulating the learning issue into one construct that is, formulating the learning issue. The purpose of this combination is because both constructs involve the same learning process. In addition, Ibrahim and Jamaludin [2], separates the constructs of planning and implementing plans in solving learning issues into two different constructs. This is because students need to plan in advance the learning actions that will be taken before implementing learning actions, in resolving learning issues. Accordingly, the constructs of the self-directed learning process defined by Ibrahim and Jamaludin [2] are: (i) formulate learning issues, (ii) plan learning actions, (iii) implement learning actions, (iv) apply new knowledge to problem-solving and (v) make a reflection of the problem-solving process.

In short, the concept of self-directed learning refers to the actions that need to be done by students throughout the learning process, starting with the presentation of the problem by the teacher and the solution for the problem given by the students. Thus, the main skills involved throughout the self-directed learning process are: (i) planning a problem solving process [36], (ii) analyse, assess understanding, provide justification and reflect learning process [2,16] and (iii) evaluate references and information [2, 16].

Previous studies on self-directed learning only focus on the effect of self-directed learning on students' attitudes and achievement such as studies done by Abdullah et al., and Cho and Kwang [1, 37] but less research is conducted in investigating the process of self-directed learning that occurs throughout the learning process [2, 38]. Thus, there is a need to know how students carry out the process of self-directed learning at each phase [38], especially in face-to-face and online learning environments. Accordingly, this study fills the gap of previous studies in investigating how students conduct self-directed learning processes and how students apply these skills to improve their mastery in chemistry learning especially in the Three Representation Level of Chemistry concept.

Three Representation Levels of Chemistry and BPBL

Chemistry encompasses the study of matter and its changes [39]. Descriptions related to chemical knowledge are structured into specific concepts. Most chemical concepts are abstract [40] thus making them complex and difficult to be mastered [41]. The Three Representation Level of Chemistry that comprises macroscopic, microscopic, and symbolic levels is an example of a concept that is difficult for the student to master [6, 42, 43].

The macroscopic representation level refers to phenomena that can be held, seen, and smell such as seeing color changes in chemical reactions [44]. The microscopic representation level relates to the theory of particles of matter referring to atoms, molecules, and ions [45]. The level of symbolic representation, on the other hand, consists of equations and chemical formulae that represent microscopic representations [46].

Gilbert and Treagust [13] as well as Johnstone [46] assert that an understanding of these Three Representation Levels of Chemistry influences students' abilities in mastering chemistry subjects as a whole. According to Johnstone [46], the teaching of the Three Representation Levels of Chemical Concept should be carried out starting from the level of macroscopic representation, followed by the level of symbolic and microscopic representation. This is because the level of macroscopic and symbolic representation is authentic while the level of microscopic representation involves understanding at the molecular level which can only be explained through the Atomic Theory of Matter [46].

Nevertheless, it was found that teachers in schools teach this concept in an unstructured manner [6, 47] around with each other. Accordingly, through this study, thinking tools or FILA chart (in problem 1) will be utilized to help students to learn this concept in an organized manner from macroscopic, microscopic, and symbolic ideas as in Table 1.

Previous studies have proven that mastery of the Three Representation Level of Chemistry Concept can be enhanced through discussion sessions [11, 44, 48]. Through discussion activities, students have the opportunity to analyze and re-evaluate their respective understandings [39, 49]. Therefore, in this study, students are given the advantage to discuss in face-to-face learning mode and an online learning mode that is through online discussion forums.

In addition, the integration of technology such as the use of animation and simulation able to improve the visualization process of students [1, 3, 5, 6, 23, 32] thus enhance the mastery of students in this concept especially regarding macroscopic level [43, 50].

However, technology integration alone is insufficient to enhance students' mastery of this concept [15, 30, 51]. The study of Abubakar and Arshad, and Waight et al. [16, 51] found that students still rely on teacher guidance during learning and teaching sessions because they are not yet able to fully control their learning. This is closely related to the self-directed learning process which refers to students' ability to determine and control their learning [5, 38]. Thus, teacher guidance should complement the needs of students in line with the concept of scaffolding emphasised by Vygotsky [20].

Methodology

Research Design

This study uses a qualitative approach through exploratory and explanatory case study design. The use of this design is appropriate as at the moment there are only a limited number of schools that implement BPBL, making this case unique to be studied [52].

Research Participants

In this study, a purposive sampling technique was employed to specifically select research participants that suit the purpose of the study. These participants were selected based on the following criteria:

1. Students in a full boarding school
2. Students who attend classes that are provided by the institution
3. Students who are in Form 4 and learning Chemistry as one of the compulsory subjects.

Based on the above criteria, two out of 69 boarding schools were randomly selected. Sample selection was continued by taking only one class from each school. Therefore, the study is limited to the data collected from these two groups to investigate the process of self-directed learning through the implementation of BPBL. Overall, the sample for this study consisted of two teachers and 20 students. This BPBL strategy was implemented for 12 weeks, focusing on two problems: (i) toothache (acid-base topic), and (ii) air pollution (redox reaction topic).

Data Collection and analysis

Data were collected from three main sources: (i) observation, (ii) student documents, and (iii) interview. For observation, an observation note was utilized to describe the

observations (verbal and non-verbal behaviors) of the self-directed learning process [53]. This data was validated by a panel of experts during the pilot study. During this process, the researcher acted as a non-participant observer, in order to avoid disruption of the natural teaching and learning environment of the participants [52]. The observation notes were supported with video and audio recordings. On the other hand, the documents were collected from a number of resources such as: (i) thinking tools (FILA chart; in problem 1), (ii) solution of learning issues and (iii) reflection journal. The FILA chart is a graphic organizer that gathers Facts (F), Ideas (I), Learning Issues (I), and Actions (A) to help students undergo a systematic self-directed learning process [19]. In this study, the FILA chart has been revised by Tolu et al., and Szymkowiak et al. [7, 30] by including the concept of three levels of chemical representation in the idea section as in Table 1.

Table 1:
FILA chart.

Column	Explanation
Fact	The facts are expressed through a given problem scenario.
Macroscopic Idea	Ideas related to the facts identified.
Microscopic Idea	Related to the Theory of Matter Particles which consists of atoms, molecules and ions (if applicable).
Symbolic Idea	Related to symbols such as chemical formulas and chemical equations.
Learning Issues	Questions that need to be addressed.
Action	Ways/activities/methods that need to be implemented to get answers to the learning issues.

The solution of learning issues refers to the answer completed by the students to the problem that has been distributed in each group. Next, the reflection journal refers to the questions posed after students completed the self-directed learning process to further understand their experiences. These questions have been validated by the experts and tested for reliability during the pilot study. On the other hand, semi-structured interviews were conducted in groups to identify the differences in the self-directed learning process of each group in establishing the facts, ideas, issues and learning actions in the FILA chart (problem 1) and thinking tool (problem 2). These questions were also validated by the experts.

Next, the collected data was analyzed thematically according to the steps suggested by Braun dan Clarke (2006). The overall process is presented in the following figure.

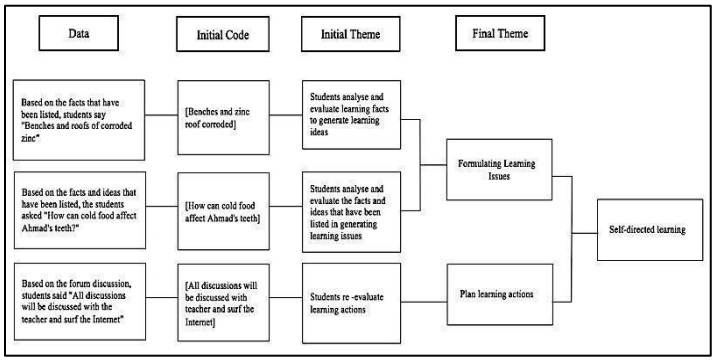


Figure 2: Example of the thematic analysis of data

Result and Discussion

Planning a Problem Solving Process

The findings suggested that the students were able to: (i) listing the order of learning processes, and (ii) determining thinking tools to be used during the problem-solving process, in planning a problem solving process. This showed that the students were able to apply SDL skills in the BPBL.

These skills reflect the self-directed learning process that allows students freedom in determining the relevant problem-solving process independently [19, 33, 35]. It was found that in Problem 2 (air pollution), students applied both skills in solving the learning issue, which was an extended mastery from Problem 1 (toothache).

At the beginning of this lesson, the teacher asked "What are the steps of the problem solving process that you should follow?". In response, students listed the order of the learning process through a discussion session. One of the students specifically mentioned that: *"Introduction of the new learning problem, suggestion for problem solution, problem follow-up and reflection"*. This shown that students were able to self-direct their learning, especially in planning steps to find relevant solutions.

The students were also able to explore new information and develop more effective thinking tools to facilitate information organization processes. It was evident that students utilized X-mind (a thinking software) to organize their thinking and information as they found that the FILA chart was inadequate. The following excerpt illustrates this finding:

Interviewer: *Why did your group utilize a thinking tool in the form of mind maps as opposed to the existing FILA chart?* [I2G2P2Q1]

Student A2: *One of the shortcomings of the FILA chart is… it is difficult to see the relationship between facts, macroscopic ideas, microscopic ideas and symbolic ideas. Through this mind map, we can use connecting lines in making connections between facts, macroscopic ideas, microscopic ideas and symbolic ideas.* [I2G2P2A1]

Based on the above interview excerpt, it was found that among the disadvantages of using the FILA chart was that students found it difficult to see the relationship between facts, macroscopic ideas, microscopic ideas and symbolic ideas. Therefore, they sought alternatives by creating a new thinking tool to replace the FILA chart as shown in Figure 3.

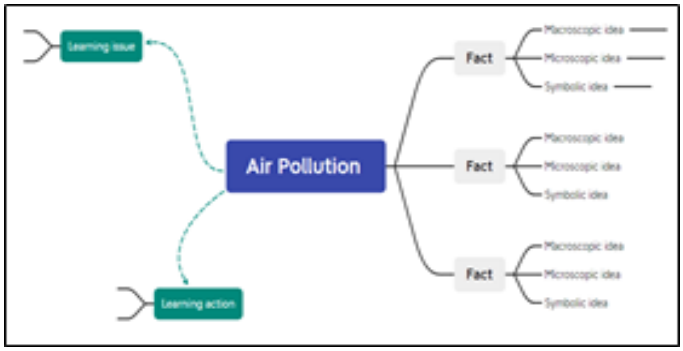


Figure 3:An example of a thinking tool utilized by students.

Figure 3 shows a thinking tool (mind map) developed by students through X-mind software. Mind maps are among the effective thinking tools [54]. Clearly, students were able to independently make connections between the learning issues, facts, learning actions and measures to overcome the air pollution. This provides evidence on how SDL skills are being applied in the BPBL, which answered the first research questions.

Interestingly, the actions exemplified by the students were able to enhance their understanding of three different levels of Chemistry: macroscopic, microscopic and symbolic representation. Evidently, the students were aware of this concept which was found to be lacking in the traditional classroom practices [6, 8]. Students' ability to list the order of learning processes, and determine thinking tools to be used during the problem-solving process benefited students in terms of their ability to identify these complex concepts and develop an effective problem solving solution.

4.2 Analyse, assess understanding, provide justification and reflect the learning process

In the process of self-directed learning through the implementation in the BPBL, the students were found to be able to analyze, assess and justify their opinions and facts for problem solutions. Specifically, it was found that the self-directed learning skills applied by the students were: (i) analysing and re-evaluating the ideas, issues and actions that have been listed, (ii) assessing understanding and justifying problem solving and (iii) reflect the learning process undergone.

Since the BPBL utilized an online forum discussion platform, students have taken initiative to discuss their ideas and sought feedback from their classmates. Undeniably, this is one of the major strengths of an online forum [55]. Students were less dependent on their teacher and instead, they continuously analyse and re-evaluate their ideas, issues and actions that should be taken to solve the problem.

For instance, in solving Problem 2 (air pollution), students were able to conduct an in-depth discussion and list the facts, ideas, learning issues and action plans to address the given problem. In Figure 4, it was found that students were able to classify the facts at

three representation levels of Chemistry. Clearly, this provides evidence of how successful self-directed learning in BPBL is in developing students' mastery of this abstract concept.

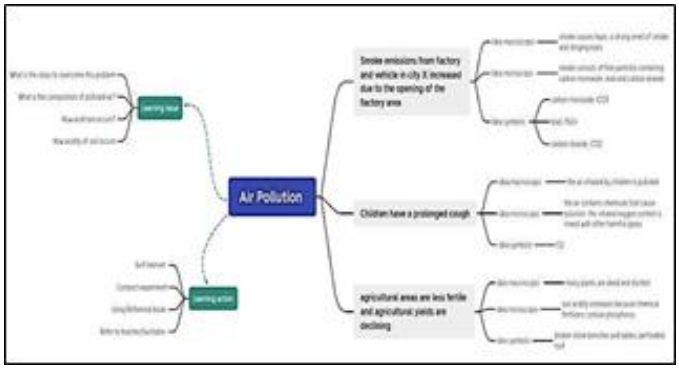


Figure 4:An example of facts, learning ideas, learning issues and learning actions suggested by students

Interestingly, this process also allowed the teacher to intervene in encouraging students to evaluate their responses and check their understanding. For instance, as illustrated in Figure 5, the teacher prompted a question in response to Student C's misconception. Instead of providing an accurate answer, the question raised by the teacher has helped students to realize their mistakes.

Student C:
Nice mind map but is carbon monoxide, CO_3?

Teacher:
Carbon monoxide, CO_3?

Student B2:
We are sorry, we will check the answer.

Figure 5:An example of how students analyse and re-evaluate the listed learning idea (symbolic)

Thus, they have re-evaluated their answer and changed the chemical formula of carbon monoxide from CO_3 to CO as illustrated in Table 2.

Table 2

Comparison between the thinking tool 1 and 2.

Thinking tool 1	Thinking tool 2
Carbon monoxide, CO3	Carbon monoxide, CO

Clearly, when the students were able to apply the self-directed learning skills via the BPBL, simultaneously their mastery of Chemistry learning were also enhanced. Evidently, students' ability to correct errors in the chemical formula of carbon monoxide was a result

of analyzing and re-evaluating ideas (between groups) and follow-up discussions in online forums. Again, this highlights the importance of online learning platforms in extending opportunities for students to develop their understanding even outside the classroom instruction hour [55]. This interaction is clearly beneficial for knowledge construction as depicted in the Constructivism Theory [20]. Besides, it was found that students utilized analyzing and re-evaluating skills in their action plans. In gaining a better understanding, the BPBL encourages students to propose an action plan in order to get the solution for the listed learning issues [2].

For instance, it was found that in the initial phase (refer to Table 3), students only suggested internet surfing as an actions to gather information. However, once they were able to analyse and re-evaluate their action plan, they suggested three additional actions such as conducting experiments, referring to reference books and consulting their teacher for clarification.

Table 3

Comparison between action plan in the thinking tool 1 and 2.

Thinking tool 1	Thinking tool 2
Surf the internet	Surf the internet Conduct experiment Refer to the reference book Consult teacher/facilitator

Moreover, the interview excerpt below revealed that the decision to change their action plan was the result of analysing and evaluating the action plan proposed by the other groups:

Interviewer :	*Why is there a change in the 'action' column between thinking tool 1 and thinking tool 2?* [I1G2P1Q11]
Student A2:	*We added actions taken after analyzing actions in other group information organization tools and we discussed them again.* [I1G2P1Q11]

Again, this highlights the strength of online learning discussion to enhance students' self-directed learning skills (Bervell, Umar & Kamilin, 2020) and proves that students' interactions are vital for learning [20].

Students were found to be actively involved in assessing understanding of their own and others especially during the group presentation. In problem 1 (toothache), one of the students asked: "*What is the pH value of alkali needed to neutralise the acid found in the mouth?*".In response, the students gave a justification related to the solution of the problem by specifically stating that *"Ahmad uses weak alkali because the acid produced in the mouth is a weak acid. The pH value of weak alkalis are in the range of 8-11".*

This shows that students are able to apply the concept of neutralisation where weak acids can neutralise weak alkalis based on the concentration of hydrogen ions (H^+) and hydroxyl ions (OH^-), thus giving the impression that they have master the level of

microscopic representation which related to the particles (H^+ and OH^- ions). This provides a strong justification to support how BPBL enhances Chemistry learning.

In addition, the skill of assessing understanding and providing justification was also exemplified by students in problem 2 (air pollution). During the presentation, students evaluated the solution of learning issues by asking: "*What is the best solution to this problem*". The group responded to the question with a relevant justification as follow:

"The best solution in overcoming the problem of air pollution is to use a scrubber on the chimney for each factory. This can prevent the release of sulfur dioxide (SO_2) and nitrogen dioxide (NO_2). Zinc reacts with nitric acid causing zinc to leak which involves the reaction equation namely: $Zn + 2HNO_3 \rightarrow Zn(NO_3)_2 + H_2$".

Therefore, it is relevant to state that students were able to justify their answer at Three Represention of Level Chemistry concept, which was poorly developed through the traditional teaching method as been discussed by Raub et al., and Omar et al. [8, 43]. This ability is important to enhance Chemistry learning as students were found to be struggling to master this abstract concept.

Lastly, it was found that students were able to reflect on their overall learning process by completing a post-problem reflective journal, which was available in the BPBL module. The findings of the study indicated that most students were able to make connections between the concepts of chemistry learned and examples from their daily activities. The following excerpt was taken from the reflective journal:

"Through the learning process, I was able to apply the concept of chemistry to a given problem easily" [JRP2Q1C1]

"After going through this BPBL learning process, the first step which I will take in solving the problem is to determine the chemical concepts involved first" [JRP2Q1B2]

Again, the ability of students in reflecting on their learning has proven that the implementation of BPBL allows students to carry out self-monitoring which is highly emphasised in the process of self-directed learning [16]. This situation allows them to solve problems more systematically and effectively after going through the implementation of BPBL. This is because student problem solving is more focused on the chemical concepts being tested.

Evaluate references and information

In this study, through BPBL, it was found that students were able to evaluate references and information by: (i) evaluating the reliability of the references, and (ii) analysing and evaluating the information presented. In accordance with the self-directed learning process, students are given the freedom to choose whether to use references from the internet or in-class materials such as textbooks and reference books.

Through the use of the internet, students have the opportunity to obtain a variety of information from various sources without limitations of place, space and time [30]. However, not all sources of information available on the internet are reliable. Therefore, students need to evaluate the reliability of a source first before obtaining information from that particular source [7]. This skill is vital to help enhance Chemistry learning.

To exemplify this point, in problem 1 (toothache), the teacher reminded the students to only obtain information from a reliable source. The teacher specifically mentioned that: "Please make sure you get the information from an established website". Accordingly,

students obtained the information by only referring to reliable references. This is evident from the following excerpt:

Interviewer : *How do you ensure that every piece of information obtained is from a reliable reference source?* [I1P1Q9]

Student D1 : *First, I will get the information from established websites and not from blogs.*[I1D1P1A9]

Interviewer : *What is an established website?* [I1D2P1S10]

Student D1 : *For example, websites from the government* [I1D2P1A10]

The distinction between reliable and non-reliable reference sources is based on the accuracy and credibility of the information presented [7]. This is because the information from recognised websites such as the website of the Ministry of Health Malaysia (MOE) has undergone review and evaluation by the authorities before being uploaded to the internet [7]. On the other hand, there is no review and evaluation of information from unrecognised websites such as blogs.

The ability of students in obtaining information from reliable sources is contrary to the findings of the study of Lau et al. [5] who found that students faced problems in selecting reference sources from recognized websites. This indicates that in this research, students were able to independently evaluate the reliability and appropriateness of the references, which in turn will help them to better understand the concepts learned in this subject.

Moreover, among the advantages of the internet is the use of animated videos that help students in visualising the Concept of Three Levels of Chemical Representation especially at the microscopic representation level [43]. This is supported by the following interview excerpt:

Interviewer : *What are the advantages of using such animated videos?* [I1P1Q9]

Student D2 : *The use of animated videos can improve visualization abilities compared to the use of books. Through animated videos, I better understand molecules and so on.* [I1D2P1A9]

The analysis of the interviews showed that the students chose the animated video as a reference because they were able to visualise particles that are difficult to see with the naked eye such as atoms and molecules. This is in line with the findings of the previous studies by [11, 29, 44, 50, 56, 57]who stated that the use of animated video can improve mastery of the Three Representation Level of Chemistry Concept especially in visualising microscopic levels of representation that can only be described through The Atomic Theory of Matter. Even though students were given the freedom to find their references,

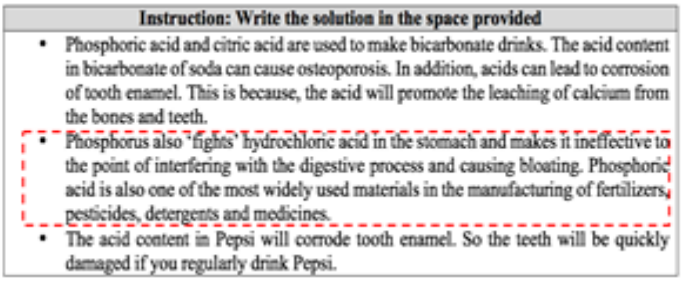
they were able to choose resources that suited their task. For example, some students chose sources from books as they did not need to analyse and evaluate the tremendous of information from the internet. This is because the information from the book is more concise and accurate. The following excerpt illustrates this point

Interviewer : *What is the best source?* [I2C1P2Q11]

Student C1 : *If the reference is from the internet, not everything can be used. The teacher reminded us that not all materials available on the Internet are acceptable. But if it's a book, the information is accurate but often not enough. So I think, the combination of the internet and books, the combination of the two is okay.* [I2C1P2A11]

This situation shows that the combination of online and face-to-face learning modes offers flexibility where students are given the opportunity to choose reference sources according to their comfort. Based on the feedback, it was found that students were able to analyse reference sources and select specific references along with justification. This finding contradicted with research done by Baysal [58] who found that, students stated that the references given were insufficient thus complicating the problem solving process. This situation occurs because the materials provided to students are not diverse which only focuses on books and newspaper clippings only, in contrast to this study where reference materials include hardcopy materials such as books and softcopy from Internet.

Next, students analysed and evaluated, processed the information as well as subsequently utilized the information in generating solutions to learning issues. Through these skills, students were able to monitor the solution of group member learning issues to ensure that no group member copies information directly from reference sources. This was because there were students who only copied information directly from the sources as shown in Figure 6.


Instruction: Write the solution in the space provided

- Phosphoric acid and citric acid are used to make bicarbonate drinks. The acid content in bicarbonate of soda can cause osteoporosis. In addition, acids can lead to corrosion of tooth enamel. This is because, the acid will promote the leaching of calcium from the bones and teeth.
- Phosphorus also 'fights' hydrochloric acid in the stomach and makes it ineffective to the point of interfering with the digestive process and causing bloating. Phosphoric acid is also one of the most widely used materials in the manufacturing of fertilizers, pesticides, detergents and medicines.
- The acid content in Pepsi will corrode tooth enamel. So the teeth will be quickly damaged if you regularly drink Pepsi.

Figure 6: Examples of students' answers copying information from reference sources

Referring to Figure 6, Student C2 copied the information directly from the source. She wrote: *"Phosphorus also fights hydrochloric acid in the stomach and makes it ineffective to disrupt the digestive process and cause bloating and phosphorus acid is widely used in the industry of fertilizers, pesticides and detergents*" which was not related to problem 1

(toothache). Fortunately, Student E2 was able to detect mistakes made by Student C2 and posed the question *"C2, did you copy directly from the reference source (copy-paste)?*

Clearly, the ability to detect this problem (copy-paste the information) was made easy as the students were able to access and review all solutions of their peer's learning issues on the online platform. Thus, this proves that the self-directed learning skills that allow freedom for students to determine the course of the learning process [36] can be enhanced through interaction between students and other peers. Again, this indicates that the SDL skills enhanced through BPBL help students to have a better understanding and mastery of the Three Representation Level of Chemistry concept.

Conclusion

In short, the findings indicated that students were able to exemplify three important SDL skills through BPBP which include: (i) plan a problem-solving process, (ii) analyze, assess understanding, provide justification and reflect the process as well as (iii) evaluate references and information. By mastering all these skills, students can come up with the best solution for the given problems which involves the Three Representation Level of Chemistry concept (macroscopic, microscopic, and symbolic). The integration of online learning mode through BPBL offers several advantages in enhancing students' self-directed learning process. Through online discussion forums, students have the opportunity to exchange ideas by involving the whole students in a class. This is in contrast with the previous studies which only involve small group discussion, mainly completed via face-to-face learning mode. The increased students' interaction (discussions involving the whole class) has enhanced their ability to master self-directed learning skills in line with Vygotsky's social constructivism, which stated that new knowledge is constructed by students through their interaction with the environment. Evidently, in this study, with the mastery of SDL skills, the students were able to overcome the poor mastery of the Three Representation Level of Chemistry concept. On the other hand, this study adds new insights on how the integration of both face-to-face and online learning platforms enhances self-directed learning skills and at the same time enhances Chemistry learning. For further study, it is recommended to investigate each self-directed learning skill that is found in this study, with different concepts or subjects to enhance students' mastery in learning.

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