

# The Development of Problem-Based Learning Module Using ADDIE Model for Physical and Online Secondary Chemistry Education Classroom

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## Abstract

The advancement of the country's development aligning with Industrial Revolution 4.0 has required talents that possess knowledge in the science and technology field. Besides, graduates should also equip themselves with a variety of soft skills and thinking skills to deal with challenges or make new opportunities. As such, students in the current generation have adapted to many learning approaches, which include online learning. Multiple approaches have been introduced in Malaysian curriculum to sharpen students' thinking skills and diversify their learning opportunities, yet one of them is problem-based learning (PBL). However, there is scarce number of research contribute to the learning of chemistry through online lesson utilizing PBL approach. This research aimed to 1. Develop a problem-based learning teaching module for the topic of carbon compounds for physical and online classrooms and 2. Identify the suitability of the teaching module to be applied in the physical classroom and online lesson. This study utilized ADDIE instructional model in constructing the module. The module was constructed according to the chemistry national curriculum on the topic of carbon compounds. The validation of the module has a remarkable comment in terms of fulfilment of objectives, suitability of method of delivery the module content and the relevance of the problem used to sharpen student's cognitive skills. The validators also added suggestions for improvement of the PBL module which is to explain how PBL works and provide more explanation on the problems.

*Keywords:* Problem-based learning, thinking skills, teaching module, chemistry, carbon compound

## Abstrak

Kemajuan pembangunan negara selaras dengan Revolusi Industri 4.0 memerlukan bakat yang mempunyai pengetahuan dalam bidang sains dan teknologi. Selain itu, graduan juga harus melengkapkan diri dengan pelbagai kemahiran insaniah dan kemahiran berfikir untuk menangani cabaran atau mencipta peluang baharu. Oleh itu, pelajar dalam generasi kini telah menyesuaikan diri dengan banyak pendekatan pembelajaran, termasuk pembelajaran dalam talian. Pelbagai pendekatan telah diperkenalkan dalam kurikulum Malaysia untuk mengasah kemahiran berfikir pelajar dan mempelbagaikan peluang pembelajaran mereka, namun salah satunya ialah pembelajaran berasaskan masalah (PBL). Walau bagaimanapun, terdapat sedikit jumlah penyelidikan yang menyumbang kepada pembelajaran kimia melalui pelajaran dalam talian menggunakan pendekatan PBL. Penyelidikan ini bertujuan untuk 1. Membangunkan modul pengajaran pembelajaran berasaskan masalah bagi topik sebatian karbon bagi bilik darjah fizikal dan atas talian dan 2. Mengenal pasti kesesuaian modul pengajaran untuk diaplikasikan dalam bilik darjah fizikal dan pelajaran dalam talian. Kajian ini menggunakan model pengajaran ADDIE dalam membina modul. Modul ini dibina mengikut kurikulum kebangsaan kimia mengenai topik sebatian karbon. Hasil dapatan mendapati modul menepati dari segi pemenuhan objektif, kesesuaian kaedah penyampaian kandungan modul dan perkaitan masalah yang digunakan untuk menajamkan kemahiran kognitif pelajar. Selain itu, terdapat juga cadangan bagi menambahkan modul PBL iaitu menerangkan PBL berfungsi dan memberikan penjelasan lebih lanjut tentang masalah yang diberikan.

*Kata kunci:* Pembelajaran berasaskan masalah, kemahiran berfikir, modul pengajaran, kimia, sebatian karbon

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## 1.0 INTRODUCTION

As the global education system is impacted by the transformation from Industrial Revolution to 4.0, more countries are facing the dilemma of the shortage of high-tech talents (Nafea & Toplu, 2021). For the country to stay on top of the industrial revolution, the education system is required to train more people with problem-solving skills and critical thinking skills to meet the country's economic and technological advances. Especially in chemistry education, many teaching strategies are used to cultivate students' critical thinking, creative thinking, analytical thinking and problem-solving skills (Aidoo, Boateng, Kissi, & Ofori, 2016; Saido, Siraj, Nordin, & Al\_Amedy, 2018).

The 4th Industrial Revolution has also made the acquirement of 21st-century skills crucial for our future generation. It drives a monumental change in the Malaysian education system, curriculum and pedagogy being used to uplift students with a variety of skills including critical thinking, problem-solving, communication and collaboration skills, etc (Oke & Fernandes, 2020). 21st-century learning exposes students to several teaching models to cultivate and provoke their minds, enhancing their cognitive ability (Anazifa & Djukri, 2017).

One of the methods used in problem-based learning. It is an approach aimed to develop problem-solving skills through self-directed learning to engage students in real-world situations.

The construction of the module utilised problem-based learning so that students can apply the abilities and skills acquired in the problem-solving process to real life and solve real-world problems, especially scientific and conceptual problems (Novalinda, Giatman, & Fajra, 2020). In addition, the topic chosen carbon compounds from form 5 chemistry curriculum as fat is the carbon compound most closely related to human daily life. The subtopic of fat was chosen as the main problem to look into, as fat can cause high cholesterol and blood lipids and bring various health problems (Xu, Li, Adams, Kubena, & Guo, 2018).

Concerning the need of enhancing students' problem-solving ability, this study aimed to 1. Develop a problem-based learning teaching module for the topic of carbon compounds under the pandemic of Covid-19 and 2. Identify the suitability of the teaching module to be applied in physical classrooms and online lessons.

## 2.0 LITERATURE REVIEW

Problem-based learning was first proposed by Barrows and Tamblyn of the Milton McMaster University School of Medicine project in 1960. For medical students to see the correlation between a large number of medical textbooks and actual cases, a learning method that can stimulate students' enthusiasm for learning is developed (Barrows, 1996). In this learning process, questions with more practical application value are adopted, which further enhances students' learning motivation, personal professional attitude, and group cooperation (Moust, Bouhuijs, & Schmidt, 2021). Subsequently, PBL was promoted in other medical schools, and then gradually applied to various disciplines and industries, such as law, finance, science etc. of K-12 education.

However, in the current condition, students often struggle to solve a problem being assigned (Ismail, Harun, Zakaria, & Salleh, 2018). Students' weak problem-solving skills can be seen when the critical insight of the problem could not be gained, resulting in the lack of ability to seek relevant information, and analyse and evaluate them critically. One of the reasons students faced difficulties in solving problems is because they did not understand the applicability of the concept learned in the real-world context or problem. Furthermore, students often use poor problem-solving approaches and strategies as they were used to rote memorisation (Yuriev, Naidu, Schembri, & Short, 2017). Although students are provided with materials, they do not know the structured steps to be applied throughout the process of solving the issue (Malmia et al., 2019). Their role as passive learners has been challenged as they were used to relying on teachers to guide them step-by-step. Teachers at this point play a crucial role in providing a linkage and scaffolding them to utilise their prior knowledge to solve the given problem. Thus, it is vital to provide a guide for teachers on how to scaffold the students to complete their tasks and come out with solutions relevant to the problem given.

Furthermore, theoretical knowledge about fats is abstract by only understanding their structure and properties. Students assume that chemistry concepts are hard and far from reality (Penn & Ramnarain, 2019), resulting in them only memorising the important concept just enough to tackle examination questions. Though, the topic of carbon compound are abstract since it has been explain in term of molecular structure. In addition, students are unable to link the concept learnt in the topic of carbon compound in daily healthy problem. There are currently lack of teaching module that focuses on relating carbon compound to the authentic problem, especially the problem of obesity which are prevalent in Malaysia (Mohd-Sidik, Lekhraj, & Foo, 2021).

This module aimed to solve the difficulties of students to relate the issue arising from a diet with fats with its properties. Through this module, it is expected that students will be trained on the ability to search for relevant information about fat-related diseases, understand the properties and sources of fats, analyse, and evaluate the effect of the amount of intake on health effect.

## 3.0 METHODOLOGY

The module would present a suitable teaching activity that could be implemented in chemistry lessons through one of the constructivist models, PBL. It is designed to cope with the pandemic of COVID-19 where there will be a possibility of conducting physical classes and online classes. This study utilized ADDIE instructional model in constructing the module. The module was constructed according to the Malaysian chemistry curriculum on the topic of carbon compounds. There are five stages applied while constructing this module including analysis, design, development, implementation and evaluation, and the steps are summarised in Table 1.

**Table 1** The Application of ADDIE for PBL Teaching Module

ADDIE	Activity
Analysis	Content analysis is done through literature by identifying the authentic problem that happened among students in a chemistry lesson.
Design	<p>Planning of development of problem-based learning teaching module suitable for a physical and online lesson under the chemistry topic of carbon compounds. There are 5 main steps involved in the PBL learning process (Hung, Jonassen, &amp; Liu, 2008):</p> <ul style="list-style-type: none"> <li>• Students think and reason about the problem in the context of the problem set by the teacher in advance based on the given topic.</li> <li>• Students are divided into groups and choose their assigned tasks according to their abilities or wishes. Each member of the group starts to collect relevant materials and information from different channels and platforms.</li> <li>• Members then shared and explained the data and information they collected. Students explore the underlying knowledge concepts behind the problem on a deeper level and broaden and deepen their understanding of the problem.</li> <li>• Learning results will be displayed to other groups and teachers in the form of slides, reports, and writing articles.</li> </ul>

	<ul style="list-style-type: none"> <li>Based on the teacher's comments, they reconsider whether they understand the problem well to avoid misunderstanding and deviation in the process of learning new concepts and mastering new skills.</li> </ul>
Development Implementation	Developing the PBL teaching module to be used in this study. PBL teaching module is anticipated to be used by teachers who teach upper secondary science stream for the suitability of the module.
Evaluation	The effectiveness of the PBL teaching module was evaluated among experts. The evaluation of this module is conducted by validation of 6 validators through open-ended questions. 10 validation questions are being constructed based on the objective, content, method of delivery and overall satisfaction. The result from the validation was analysed to assess whether the teaching module was suitable to be used.

After the development of the module, it was then validated by the expert (see Table 2). The lesson plan is constructed and is validated among expert who has a science background and currently teaching chemistry at the secondary or university level. The module has been validated by 5 validators, which cons of 2 females and 3 males, followed by interviewing the 5 validators. All of them have at least 3 years of teaching experience using PBL and are familiar with online teaching. One of the validators teaches at the university level and the rest are at the secondary level. Validators rated them according to scales, 1- does not fulfil, 2- less fulfil, 3- moderately fulfil, 4- fulfil, and 5- outstanding on four categories, which includes the fulfilment of objectives, suitability of the method of delivery, the content of the module and the relevance of the problem used to sharpen students' cognitive skills. The experts were interviewed as well and gave additional comments to elaborate on their thought according to score given.

Table 2 Validation Form

Criteria	1	2	3	4	5
This module helps to cultivate students' problem-solving skills through exposure to problems related to fats. This module provides guidance on students to solve problems utilising the chemistry knowledge. This module uses appropriate method in physical and online lesson.					
PBL approach is suitable to be used as a teaching approach to understand the topic of carbon compound. The content in this module is appropriate for students in secondary level.					
The content in the module helps students in solving problems in their assessment as well as daily problems. The problem used in this module are related to their curriculum.					
The problem used increase the awareness of them towards authentic problems happened in life,					

#### 4.0 RESULTS

This module is to provide suggested PBL activity to be implemented in a Form 5 Chemistry classroom, on the topic of carbon compounds. This topic will be chosen because of its association with organisms. Carbon compounds focusing on fats are closely related to our daily life such as our daily diet, and things that we used like rubber or palm oil. The topic of interest is Form 5 Chemistry Chapter 2, Topic 2.8: Evaluating Fats. Two lesson plans were being proposed, which includes a lesson in physical class or through online learning.

In physical class, students will be asked to investigate the problem, of obesity and analyse how fats in diet could cause obesity. Students would need to gather data according to their group and present their findings through role-playing, in the form of a news broadcast. Teachers will assess their presentation according to the checklist, aligning with learning objectives from the chemistry curriculum. The lesson plan is as shown in Table 3:

Table 3 Lesson Plan According to 5 stages of PBL in Physical Class

Stages	Lesson Plan	Duration
Encounter and Reason Through the Problem	<ul style="list-style-type: none"> <li>At the beginning of the course, students were shown pictures and recent news about obese people.</li> <li>Ask students to give their opinions on the main factors that cause obesity. The main factors include high-calorie and high-fat fast food, drinks with high sugar content and so on.</li> <li>Summarize the students' opinions and set the discussion section of this lesson with the answers given by the students. How does high fat intake lead to obesity?</li> </ul>	20 minutes
Self-Directed Study	<ul style="list-style-type: none"> <li>Students were divided into a group of four to six.</li> </ul>	40 minutes

Share Their Learning with The Group and Revisit The Problem, Generating Additional Hypotheses	<ul style="list-style-type: none"> <li>-Then students were asked to discuss the factors that cause obesity-high fat, and collect fat definition, physical and chemical characteristics, production and transformation, benefits, and disadvantages, etc. through mobile phones or computers.</li> <li>-Let students gain an understanding of the general concept of fat, and group members share and discuss how fat causes obesity.</li> <li>- Students learned from various sources that high-fat foods can lead to obesity, and obesity can lead to diabetes, kidney disease, heart disease, etc.</li> <li>- The teacher should patrol and monitor students on the collection content and collection progress during the student discussion.</li> <li>- In addition, the teacher will give the students some hints that enhance their critical thinking. For instance, if excess fat leads to obesity, what are the consequences if the body lack fats?</li> </ul>	15 minutes
Display of Learning Results	<ul style="list-style-type: none"> <li>- In this session, students report and present their materials and the conclusions of the discussion.</li> <li>- Students can present their idea through role-playing in a health tv programme that exposes all ages of the audience to the effect of fats on their diet and health.</li> <li>- The first two students acted as the host of the programme. They emphasize definition, physical and chemical properties, production and transformation, and the benefits and disadvantages of fat-related materials are reported one by one.</li> <li>- The two other students took over; role-playing as nutritionists and explained the effect caused by lacking or excessive fat intake.</li> <li>- Students should also suggest a daily intake of fats and oil in their diet to maintain good health.</li> </ul>	15 minutes
Summarize and Rethink Their Learning	<ul style="list-style-type: none"> <li>- After the members of each group reported the results, the teacher commented and asked the students to reflect on this topic again.</li> <li>- Students are asked to compare the harms and effects of two extreme forms of fat intake (excessive or no intake) on the human body so that the use and significance of fat in daily life can be correctly evaluated.</li> <li>- The teacher would assess them based on the checklist in the evaluation form.</li> </ul>	15 minutes

In online class, students will be asked to investigate the problem, of heart disease, and analyse how fats in diet could cause heart disease. Students would need to gather data according to their group and present their findings by producing a series of comics through. Teachers will assess their presentation according to the checklist presented in 3.4, aligning with learning objectives from the chemistry curriculum. Differing from the physical class, the online lesson will be conducted in two sessions on two different days to allocate enough time for them to produce their animation. The lesson plan is as shown in Table 4:

**Table 4** Lesson Plan According to 5 stages of PBL in Online Class

Stages	Lesson Plan	Duration
Encounter and Reason Through the Problem	<ul style="list-style-type: none"> <li>- Students were shown statistics of patients who died due to heart disease had increased over the years.</li> <li>- Students throw their ideas through menti.com to describe the reasons for this incident so that teachers gained the idea from their prior knowledge</li> <li>- The main factors include high-calorie and high-fat fast food, drinks with high sugar content and so on. Summarize the students' opinions and set the discussion section of this lesson with the answers given by the students. How does high fat intake lead to heart disease?</li> </ul>	20 minutes (first lesson)
Self-Directed Study	<ul style="list-style-type: none"> <li>- Students will be divided into small groups and are asked to discuss the factors that cause heart disease. They should collect information on               <ol style="list-style-type: none"> <li>(i) fat definition</li> <li>(ii) Physical and chemical characteristics</li> <li>(iii) importance and source of fats</li> <li>(iv) its production and transformation</li> <li>(v) the effect of fats (saturated and unsaturated) on health.</li> </ol> </li> <li>- they will be broken up into their discussion room and utilised the application 'Jamboard' to display their information</li> <li>- this activity allows students to gain an understanding of the general concept of fat, and group members share and discuss how fat causes heart disease.</li> </ul>	40 minutes (first lesson)
Share Their Learning with The Group and Revisit the Problem, Generating Additional Hypotheses	<ul style="list-style-type: none"> <li>- Students should be able to find out the effect of eating food high in fats on health, and the importance of fat and oils in body processes.</li> <li>- they can discuss their subtopic among their group members</li> <li>- the teacher should monitor students on the collection content and collection progress during the student discussion.</li> <li>- the teacher can direct the students on what is expected in the presentation, such as since excess fat leads to heart disease, but also the consequences of lack of fats.</li> </ul>	20 minutes (first lesson)
Display of Learning Results	<ul style="list-style-type: none"> <li>-In this session, students report and present their comics through <a href="https://www.storyboardthat.com/">https://www.storyboardthat.com/</a>. By storytelling and the conclusions of the discussion.</li> <li>- Students present their idea by producing a comic with children (age 7-12) as their target audience on the effect of fats on their diet and health.</li> <li>- The story in the comic should consist of the following subtopic               <ol style="list-style-type: none"> <li>(i) fat definition</li> <li>(ii) Physical and chemical characteristics</li> <li>(iii) importance and source of fats</li> </ol> </li> </ul>	20 minutes (second lesson)

	(iv) its production and transformation	
	(v) the effect of fats (saturated and unsaturated) on health.	
	- Students should also suggest a daily intake of fats and oil in their diet to maintain good health.	
Summarize and Rethink Their Learning	- Other classmates will be their audience and Q&A sessions will be conducted.	20 minutes
	- Teachers provide comments and ask the students to reflect on this topic again, comparing the effects of two extreme forms of fat intake, either excessively or lacking fats on the human body, so that the use and significance of fat in daily life can be correctly evaluated.	(second lesson)
	- The teacher would assess them based on the checklist in the evaluation form.	

The above module was validated by 5 experts through validation form rate them according to scales, 1- does not fulfil, 2- less fulfil, 3- moderately fulfil, 4- fulfil, and 5- outstanding on a few categories. These categories include fulfilment of objectives, suitability of method of delivery and its relevance to the problem used to sharpen student's cognitive skills. The scores obtained from the Likert scales by 5 validators include fulfilment of objectives (3.6), suitability of method of delivery (4.2), content of the module (4.4) and the relevance of the problem used (3.8).

## 5.0 DISCUSSION AND RECOMMENDATION

This module aimed to cultivate students' problem-solving skills through exposure to problems related to fats so that they can analyze and evaluate the pros and cons of fats in our life. Besides, self-directed learning is also promoted throughout the process. All validators opine that the fruitful content in the module can fulfil our module objectives. One validator also commented that the step-by-step guides exposed students to search for relevant information appropriately. Besides, all the validators also think that the teaching material in our module is related to daily life and easily understandable for students to solve the problem. The module provides enough scaffolding to help students solve real-world scenarios. However, two validators advised us to include a more instructional picture to allow a better understanding of teacher and student while using it.

All validators have affirmed that the method of delivery is effective, either in physical classes or online lessons. The PBL teaching model allows teachers to easily detect students' misconceptions, and independent learning and group cooperative learning can make them more involved in the learning process. In addition, all validators also believed that the learning materials of this module fit well with the syllabus, covering almost all the sub-topics that students need to master, and the rich graphics and texts can easily stimulate students' interest in learning. In addition, another middle school teacher from Malaysia believes that Malay schools are divided into urban schools and rural schools, and their learning levels are not the same, and they are not completely applicable.

Problem-based learning also emphasized students use the knowledge and concept they have learned in overcoming daily issues, even in an unfamiliar situation (Fidan & Tuncel, 2019). This helps students to sharpen their higher-order thinking skills and aids them in making more accurate decisions. Meanwhile, all validators agreed that these two activities are relevant to the daily application of the problem. Furthermore, 3 validators also opined that the activities we planned according to the PBL approach were able to attract the interest of Malaysian secondary students since obesity is a common problem that happens in Malaysia. It was supported by Ariaratnam et al. (2020), Mohamad Nor et al. (2018) and Mohd-Sidik et al. (2021) who highlighted the issue of obesity are prevalent in Malaysia. Yet, there were still many Malaysian who exhibit low awareness of the consequences of obesity (Peng, Hamzah, Nor, & Said, 2018). Hence, the context to be used is crucial to determine the applicability of the module to ensure students attain the learning outcome as required.

Regarding whether the content in the module can be helpful to students in the assessment, all validators believe that as long as the learning objectives of the module are consistent with the syllabus, it must be helpful. Moreover, students are given a problem to investigate the reasons and results of fats functioning in the human body, they can obtain skills to solve other problems, and students need to search and filtrate materials they need, through brainstorming and discussion and group work, this can enhance their problem-solving skills.

The expected outcome of this module is to enhance students' problem-solving skills. At the same time, it should also help students to realize the importance of the chemistry concept or knowledge learnt are closely related and helpful in our daily life. All validators agreed that this module helps students to achieve their desired learning outcome. Nevertheless, two validators highlighted that it is crucial to assess them on their understanding and mastery level before the lesson ended to ensure that they benefit from this module.

Finally, validators put forward the following suggestions for our module. One of the validators believe that if the module is used by teachers, only the lesson plan part needs to be retained. Another validator believes that if this module is provided to students who are exposed to PBL learning methods for the first time, more explanations of PBL learning methods should be added. Several other teachers believe that it is necessary to provide more exposure on problems and their consequences in the lesson plan. It helps students in diversifying their perspectives to look at the problem and integrate information throughout the learning process.

## 6.0 CONCLUSION

This module has been developed to enhance students' problem-solving skills and to prepare them for the challenges in the 21<sup>st</sup> century. The module consists of a problem-based learning teaching model in the physical class and online lesson. The module utilized carbon compounds with the subtopic of fats and adopted heart disease and obesity as a problem that students often encounter in their daily life. The validation of the module has a remarkable comment in terms of fulfilment of objectives, suitability of method of delivery and its relevance to the problem used to sharpen student's cognitive skills. However, validators have commented on its applicability across students of different

backgrounds. In addition to that, the assessment of their mastery in terms of knowledge gained should also be considered. Thus, improvements can be made where assessing students' prior knowledge and the final knowledge gained should be included in this module. The application of multimedia should also be considered when applicable to enhance the variability and liveliness of the class.

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