The Development and Validity of the Chemical Equilibria Problem-Based Learning e-Module

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Abstract – **This research aims to 1. Develop a problem-based learning e-Module for chemical equilibria to improve students' higher-order thinking skills (HOTS) and 2. Validate the e-Module. This e-Module is developed based on the ADDIE Model which consists of analysis, design, development, implementation, and evaluation. This e-Module is developed according to the Malaysian Higher School Certificate (STPM) chemistry curriculum for the topic of chemical equilibria. For e-Module validity, five experts in STEM and chemistry education were appointed to verify the content of the PBL Chemical Equilibria e-Module using the e-Module Validity Rubric, and a language expert was appointed for language validity. The average item content validity score (S-CVI) for the e-Module is 0.96, indicating that it has good and excellent content validity and is suitable for use as a teaching and learning module to improve students' HOTS. The findings of this study should benefit the development of a module focused on chemical equilibria, enhancing the learning experience for students, promoting a better understanding of concepts, and raising the average student's understanding and higher-order thinking skills on chemical equilibria.**

Keywords – **Problem-based learning, Chemical Equilibria, Higher-order thinking skills, Module development, Validity assessment**

I. INTRODUCTION

In the contemporary age of education, the study of chemistry at the form six level necessitates an inventive methodology to enhance students' comprehension and cognitive abilities. An essential obstacle lies in comprehending the intricate notion of chemical equilibria. The assertion is corroborated by prior research, which indicates that the subject of Chemical Equilibria encompasses numerous intricate ideas. Mastery of this topic can lead to the development of alternative concepts (Jusniar et al., 2020), as well as an understanding of various related concepts (Akın & Uzuntiryaki-Kondakci, 2018; Nur Syuhada & Nor Hasniza, 2021). Furthermore, global research on students' comprehension of chemical equilibria has also discovered multiple constraints in their learning of this subject matter. The limitations identified include student misconceptions regarding the nature of chemical equilibria, a lack of comprehension of the Law of Equilibria, insufficient understanding of the impact of catalysts, temperature, and concentration on equilibrium reactions, and confusion between rate and equilibrium. Moreover, prior studies have indicated that the challenge of learning about chemical equilibria is influenced by the instructional methods used and the teachers' struggles in teaching and fully understanding the concept (Cheung et al., 2009).

The 2018 report on the STPM highlighted the presence of numerous candidates who struggle with solving calculation problems related to the concept of chemical equilibria. Additionally, some candidates face difficulties in accurately interpreting energy changes based on their observations of the concept (Malaysian Examination Council, 2019). To solve the calculation issue, the student needs to initially examine and identify the information given in the question. They must then establish the connection between the knowledge about the notion of the state of matter and the concept of the mole, before arriving at the ultimate solution. The report reveals that students struggle to comprehend the concept of Chemistry. Furthermore, their proficiency in HOTS related to Chemical equilibria is inadequate, as they are unable to effectively apply their acquired knowledge to solve the presented problems. Hence, the objective of this study is to examine the development of an e-Module that not only facilitates comprehension of fundamental chemical equilibria concepts but also fosters the cultivation of advanced cognitive abilities in students. Through the utilization of technology and problem-based learning approaches, this e-Module aims to enhance the chemistry learning experience for form six students.

II. PROBLEM STATEMENT

Understanding chemical equilibria is crucial for those studying chemistry in higher education. Nonetheless, students frequently find it difficult to grasp this idea, and to fully comprehend it, HOTS is needed. Conversely, utilizing cutting-edge teaching strategies like problem-based e-Modules can help students develop their HOTS. However, up until now, no particular e-Module has been developed and thoroughly validated to teach chemical equilibria to form six students with an emphasis on enhancing HOTS.

The limits of current learning methods, as well as the lack of development of valid and efficient e-Modules for chemical equilibria, highlight the need for innovative and validated effective learning methods to improve students' HOTS. Although many research efforts on the development of chemistry learning modules have been done in Malaysia, there are still gaps in previous studies that need to be filled through this study. The justification is that most of the studies on the development of chemistry modules in Malaysia involve the development of printed modules and most of these studies focus on the topic of chemical formulas and equations (Rafidatul & Johari, 2011), chemical bonds (Minah et al., 2014), acids and base (Noor Hanizah & Shaharuddin, 2009), electrochemistry (Norhuda &

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Shaharom, 2004), mole concept (Siti Ezainora & Johari, 2011) and others. Although many misconceptions and learning challenges have been reported in previous research (Bernal-Ballen & Ladino-Ospina, 2019; Firda et al., 2020), the study of module development for the topic of chemical equilibria as a whole has still not been carried out.

To bridge this gap, the project aims to develop and validate an electronic module based on problem-based learning. This module will enhance the understanding of chemical equilibria and enhance the HOTS of form six students. Hence, the main concern that arises is: how can a proficient problem-based learning electronic module for chemical equilibria be developed and verified to assist in cultivating HOTS in form six students? This research will also address related inquiries, such as how to precisely develop this problem-based e-Module and evaluate its validity.

III. LITERATURE REVIEW

In the era of education that continues to grow, the renewal of learning approaches becomes crucial, especially in the field of chemistry at the form six level. A method that has garnered substantial attention is Problem-Based Learning (PBL), which demands students' engagement in problem-solving and has the potential to enhance critical thinking skills at an advanced level. The objective of this study is to develop and assess the validity of a problem-based learning module focused on chemical equilibria, specifically designed to enhance the HOTS of form six students.

Problem-Based Learning (PBL) in a Chemistry Context

PBL, as a learning approach, has gained recognition because of its potential to motivate students and deepen their understanding of concepts. A study conducted by Firdaus (2016) demonstrates that PBL can enhance students' HOTS. Additionally, Hmelo-Silver (2004) emphasizes the need for efficient time management and guidance from mentors. Park & Choi (2015) found that PBL has the potential to enhance students' learning attitude, critical thinking in decision-making, and appraisal of sub-field problem-solving skills. PBL is an effective method for emphasizing lifelong education as it encourages active, cooperative, and self-directed learning about specific issues relevant to professional practice. This, in turn, facilitates the transfer of information (de Jong et al., 2014). Implementing the PBL approach has the potential to enhance educational achievements. PBL facilitates meaningful learning by effectively stimulating HOTS (Blackburn, 2015).

Difficulty in Understanding Chemical Equilibria

Studies conducted by Akın and Uzuntiryaki-Kondakci (2018), Jusniar et al. (2020), and Nur Syuhada and Nor Hasniza (2021) have shown that students commonly face difficulties in understanding the concept of chemical equilibria. The findings of a preliminary study, which included thirty Chemistry teachers from various regions of the country, indicate this. Based on the preliminary findings, 26 out of 30 teachers reported that teaching the concept of equilibria is challenging, while 27 out of 30 teachers perceive it as the most difficult for students to master. Based on the feedback given by the instructor in the preliminary study, this topic is likewise regarded as difficult due to its extensive range of subtopics and abstract concepts that are difficult to visualize, such as equilibrium reactions, equilibrium laws, and Le Chatelier's principle. Moreover, previous research findings indicate that teachers face challenges in teaching and have a limited grasp of the concept of chemical equilibria. This lack of understanding on the part of teachers further complicates the learning process.

In addition, students' difficulties with chemical equilibria in chemistry may impede their understanding of other interconnected subjects such as Acids and Bases, Buffer Solutions, Salt Hydrolysis, Solubility Products, and Redox Reactions (Bernal-Ballen & Ladino-Ospina, 2019). This statement aligns with the results drawn from the 2016 STPM Examination Report. The report revealed that a significant number of candidates made errors in their calculations by neglecting to accurately determine the number of moles for a system in equilibrium and by failing to calculate the equilibrium constant with utmost accuracy. Hence, it is essential to develop teaching strategies that facilitate comprehension of this concept. Herawati and Muhtadi (2018) highlighted the necessity of utilizing visual models and simulations to improve students' understanding of chemical equilibria.

Learning Module Development

The development of learning modules is crucial in attaining the objective of PBL to enhance HOTS. Kurniawati et al. (2021) proposed that learning modules can offer systematic direction, facilitate problem-solving, and foster self-directed learning. Furthermore, a crucial factor to be taken into account in facilitating the development of chemical knowledge is the effective delivery of concepts, which may be accomplished by employing teaching tools like learning modules. A study conducted by Pratama et al. (2022) demonstrated a noteworthy enhancement in students' comprehension and proficiency by employing suitable chemistry learning material.

Students can observe the physical properties of substances, phenomena, and chemical reaction processes more easily by using learning media such as pictures, animations, simulations, and learning videos (Herawati & Muhtadi, 2018; Komikesari et al., 2020). An example of a learning media that fulfills the criterion is a portable electronic module, often known as an e-Module. E-Modules are highly conducive to self-directed learning, facilitating enhanced comprehension and effectively enhancing students' HOTS (Pane et al., 2020; Purnamasari & Utomo, 2020; Subarkah et al., 2019). Hwang et al. (2013) suggest that the utilization of technology in learning techniques can enhance students' HOTS. Nevertheless, the utilization of technology in isolation, without the implementation of suitable pedagogical methods, fails to facilitate the development of HOTS (Goldman et al., 2015). Hence, the use of technology needs to be integrated with an appropriate learning model to generate students' HOTS.

Improvement of Higher-Order Thinking Skills through PBL

HOTS become an important focus in education. The HOTS concept, as identified by Anderson and Krathwohl (2001), includes applying, analyzing, evaluating, and creating. PBL has been proven to influence students' HOTS development (Facione, 2015). The PBL model can help students learn and connect lesson content with various skills including HOTS (Hamdani, 2011). Activities in PBL can promote students' HOTS through non-routine problems that become the beginning of learning and exploration of new knowledge through independent solutions or group collaboration (Jonassen, 2011). Hence, incorporating Problem-Based Learning (PBL) into the development of the chemical learning module can greatly enhance the HOTS of form six students.

Based on the literature analysis, it is obvious that PBL and the development of learning modules significantly impact the understanding and HOTS of form six chemistry students. Yet there remains a requirement for further comprehensive and empirical investigation to verify the efficacy of problem-based learning modules within the context of chemical equilibria. The objective of this research is to fill this gap and provide novel insights into the existing body of knowledge in chemistry education.

IV. METHOD

Research Design

This e-Module employs established problem-based learning strategies to enhance students' proficiency in applying and engaging with chemical equilibria concepts within a collaborative environment, fostering teamwork and problem-solving skills. This e-Module was developed adopting the ADDIE Model, which encompasses Analysis, Design, Development, Implementation, and Evaluation. It uses a qualitative and quantitative methodology to collect data. The development of the e-Module has five distinct phases: analysis, design, development, implementation, and evaluation (Widyastuti & Susiana, 2019). The procedure at every phase is briefly outlined in Table I.

TABLE I: FIVE PHASES OF THE ADDIE MODEL FOR THE DEVELOPMENT OF PBL e-MODULE

Phase	Description
Analysis, A	The analysis phase comprises an interview study done on form six chemistry teachers and a HOTS chemical equilibria test administered to form six students. The purpose of these assessments is to ascertain the need to develop an e-Module on the topic of chemical equilibria and to evaluate the students' level of HOTS.
Design, D	The problem-based learning teaching e-Module is designed with a primary focus on two specific themes related to chemical equilibria: "Save the Atmosphere" and "Stresses on Equilibrium". The subsequent procedures often encompass the PBL learning process (Sunaryo et al., 2021; Tan, 2003): i) Students engage in research and reasoning to analyze issue scenarios within the framework of chemical equilibria, formulate initial ideas, and generate hypotheses. Students must analyze a problem and explain their findings by thoroughly evaluating all available facts. ii) Each member does research and shares the acquired information within the Group. Students convene in their designated groups and exchange the knowledge they have acquired to construct a FILA chart. iii) Students will review their difficulties and construct new knowledge. They will collaborate to experimentally verify their assumptions and suggest resolutions to issues. iv) Subsequently, the learning outcomes will be presented to both the group and the teacher creatively. v) Following the presentation, students will synthesize and reassess the theoretical knowledge acquired. Students will engage in self-reflection to enhance their understanding and rectify errors, so propelling themselves closer to the desired learning outcome. During this educational process, the teacher will guide pupils to guarantee they can effectively utilize cognitive skills to solve difficulties and select suitable techniques when encountering similar problems.
Development, D	During the development phase, the e-Module PBL Chemical Equilibria was developed by utilizing principal component analysis. This approach was determined from a needs analysis interview conducted in the previous analysis phase. The e-module development process involved creating a visually appealing and user-friendly interface, structuring the content to align with the chemical equilibria problem, and incorporating multimedia components to enhance students' understanding and problem-solving skills. The PBL e-Module has been developed and verified by experts in the relevant area to ensure its suitability for delivering to the intended learners.
Implementation, I	The PBL teaching e-Module is expected to be used by teachers who are interested in applying a problem-based learning approach in teaching chemistry.
Evaluation, E	The suitability of the PBL teaching e-Module is evaluated among experts. This e-Module Assessment is conducted with the confirmation of five experts through closed and open questions. Validation items include content quality (learning objectives and e-Module content), effectiveness potential (usability, flexibility, performance, and assessment), and overall satisfaction. In addition, the researcher also carried out e-Module validation for language validity involving a language expert. Improvements and amendments to the e-Module have been made based on feedback from validators.

e-Module PBL Chemical equilibria

In problem-based learning, scenarios or problems are presented to students to help them identify their learning objectives. The focus of this approach is not only on problem-solving but also on providing students with suitable scenarios to help them build new knowledge and understanding. Students are required to develop a model that illustrates how to save the atmosphere and identify stresses on equilibrium. They also need to come up with alternative solutions to these problems and present their ideas using the FILA chart, while proving their effectiveness.

This e-Module consists of several submodules, including a problem module, lecture module, exploration module, and glossary. The problem module presents two problem themes related to the concept of chemical equilibria: "Save the Atmosphere" and "Stresses on Equilibrium". To help students explore these themes in more depth, a lecture module containing complete notes, concept simulations, and problem-solving exercises is provided, along with an exploration module that contains links to YouTube videos, articles/journals, e-books, and other websites related to the concept of chemical equilibria. Students are required to solve both problem scenarios presented according to the specific PBL steps provided in the e-Module. This will help them deepen their understanding of chemical equilibria and improve their higher-order thinking skills.

The e-Module contains two problem themes, for which learning activities have been designed using the PBL approach. Students are required to examine the problem scenarios provided as stimulus material and identify facts, ideas, learning issues, and actions. They also need to prepare a FILA chart before submitting solutions to the identified learning issues. Throughout the problem-solving process, students can use the lecture module and exploration module to gain a deeper understanding of the concept of chemical equilibria and come up with a solution to the problem.

To complete the PBL activities, students need to research and reason about the problems, determine what they need to learn, identify resources and tools to solve problems, assess possible ways to solve problems, present solutions to problems, and build new knowledge. Finally, they need to report their findings through a presentation of their ideas.

The e-Module was developed and later validated by five experts, which included lecturers and chemistry teachers with over 10 years of experience in education and an extensive knowledge of module development. This is consistent with the recommendation of Shrotryia and Dhanda (2019), who suggested a minimum of three field experts to ensure the validity of e-Module content, without specifying a maximum number of experts. In addition, the selection of field experts in this study adhered to the criteria proposed by Akbari and Yazdanmehr (2015), which mandates that the experts have more than five years of work experience, specific experience in teaching chemistry subjects, and direct involvement in related studies such as chemistry learning management. Table II presents the panel of experts who contributed to the validation process.

TABLE II: SUMMARY OF e-MODULE CONTENT VALIDITY EXPERTS' BACKGROUND

Expert	Position	Field of Expertise	Institution	Working Experience	Highest Education Level
E1	STPM Chemistry Principal Trainer	STPM Chemistry	Form Six Centre	25 years	B.Ed
E2	STPM Chemistry Head Unit	STPM Chemistry	Form Six College	26 Years	M.Ed
E3	Lecturer	Chemistry	Matriculation College	19 Years	M.Ed
E4	Lecturer	STEM, Chemistry Education	Institute of Teacher Education	12 Years	Ph.D
E5	Senior Lecturer	Chemistry Education	Universiti Teknologi Malaysia	22 Years	Ph.D

After the experts agreed to participate in the study, they were given the e-Module Validity Rubric to evaluate the validity of the e-Module's content. They used a 5-point Likert scale to assess the quality of the content, its potential effectiveness (including usability, flexibility, performance, and assessment), and overall satisfaction. Refer to Table III for more details.

TABLE III: e-MODULE VALIDITY RUBRIC

No.	Criteria	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
	A. Content Quality	1	2	3	4	5
	A1. Learning Objectives					
1	The composition of learning objectives in the e-Module is clear.					
2	The objectives of the e-Module can be achieved based on teaching activities and strategies.					
3	The learning objectives stated for each activity are by the proposed activity and assessment.					
4	Learning objectives can achieve the goals of the e-Module.					
5	The stated learning objectives lead to the achievement of learning outcomes.					
	A2. Module Content					
6	The content of the e-Module can comply with the stated learning objectives.					
7	The content of the e-Module is complete in terms of teaching steps.					
8	The content of the e-Module is complete in terms of reinforcement exercises.					
9	The content of the e-Module is complete in terms of assessment.					
10	The content of the e-Module does not conflict with society's values.					
	B. Effectiveness Potential					
	B1. Usability					
11	The content of the e-Module can comply with the stated learning objectives.					
12	The content of the e-Module is complete in terms of teaching steps.					
13	The content of the e-Module is complete in terms of reinforcement exercises.					
14	The content of the e-Module is complete in terms of assessment.					
15	The content of the e-Module does not conflict with society's values.					
	B2. Flexibility					
16	The e-Module content can be used by any party to teach students.					
17	The e-Module content can be used by students for self-learning purposes.					
18	The level of difficulty of e-Module content such as terminology follows					

	the student's cognitive ability.
19	Higher level thinking skills can be improved based on the activities suggested in the e-Module.
20	The teaching methods used in the e-Module challenge students' HOTS.
	B3. Performance
21	The scope and sequence of topics in the e-Module are compatible with the developmental needs of students.
22	Each topic in the e-Module is organized logically and coherently according to the order of learning.
23	The time allotted for the planned activities is appropriate to the student's ability.
24	Suggestions for teaching media such as videos, simulations, diagrams, etc. are by the lesson plans in the e-Module.
25	The terms used in the e-Module are easy to understand.
	B4. Assessment
26	The teaching strategy is in line with the 5 steps of Problem-Based Learning.
27	The teaching strategies mentioned are in line with the Problem-Based Learning Model.
28	Assessment can be carried out through learning activities in the e-Module.
29	The student assessment component corresponds to the content of the e-Module.
30	The assessment given can measure the level of achievement of learning objectives.
	C. Overall Satisfaction
31	The purpose of the e-Module is clear.
32	The e-Module aims to suit the students.
33	The e-Module content is easy to understand.
34	The e-Module content is easy to convey to students.
35	The content of the e-Module can be adapted to students from various background categories.
36	The planned activities are in line with the learning objectives of this e-Module.
37	This e-Module has effective potential in teaching Chemistry subjects to students.
38	This e-Module helps foster students' problem-solving skills through exposure to problems related to Chemical equilibria.
39	This e-Module guides students to solve problems using chemical knowledge.
40	This e-Module uses appropriate methods for physical and online learning.
41	The PBL approach is suitable to be used as a teaching approach to understand the topic of Chemical equilibria.
42	The content in this e-Module is suitable for form six students and equivalent.
43	The problems used in this e-Module are related to the content of the curriculum.
44	The problems presented in the e-Module can increase students' awareness of the real problems that exist in life.
45	Overall, give your opinion on the quality of this e-Module.

As a result of the responses of the validating experts, the researcher has obtained the value of the content validity index for each item (I-CVI) and the value of the content validity index of each scale (S-CVI). Calculation of the S-CVI was carried out by finding the ratio of the incremental I-CVI results for each item received over the total number of instrument items, where the S-CVI is the average item content validity score for the e-Module. According to Grant and Davis (1997), and Polit and Beck (2006), the accepted I-CVI value $\geq$ 0.80 where a higher value indicates more appropriate content validity. This study uses the I-CVI and S-CVI calculation formulas as follows (Polit & Beck, 2006);

$$I - CVI = \frac{Agreed\ Item}{Number\ of\ Expert}$$

$$S - CVI = \frac{\sum I{-}CVI}{Number\ of\ Item}$$

The e-Module undergoes continuous improvement through the collection of suggestions, comments, and expert feedback. All feedback and suggestions received are carefully considered to enhance the content of the e-Module. This process plays a significant role in improving the quality of e-Module content.

V. FINDINGS

Content Validity

The I-CVI score for each item as validated by experts is shown in Table IV.

TABLE IV: ANALYTIC SCORING RUBRICS FOR CONTENT OF ENGLISH WRITTEN COMMUNICATION

Item	Number of Experts	Number of Agreement	I-CVI
1	5	5	1.00
2	5	5	1.00
3	5	4	0.80
4	5	5	1.00
5	5	5	1.00
6	5	5	1.00
7	5	5	1.00
8	5	4	0.80

9	5	4	0.80
10	5	5	1.00
11	5	5	1.00
12	5	5	1.00
13	5	4	0.80
14	5	4	0.80
15	5	5	1.00
16	5	4	0.80
17	5	4	0.80
18	5	5	1.00
19	5	5	1.00
20	5	5	1.00
21	5	5	1.00
22	5	5	1.00
23	5	5	1.00
24	5	5	1.00
25	5	5	1.00
26	5	5	1.00
27	5	5	1.00
28	5	4	0.80
29	5	5	1.00
30	5	5	1.00
31	5	4	0.80
32	5	5	1.00
33	5	5	1.00
34	5	5	1.00
35	5	5	1.00
36	5	5	1.00
37	5	5	1.00
38	5	5	1.00
39	5	5	1.00
40	5	5	1.00
41	5	5	1.00
42	5	5	1.00
43	5	5	1.00
44	5	5	1.00
45	5	5	1.00

The e-Module has been found to have a validity S-CVI value of 0.96, with each item's I-CVI value being above 0.80. This indicates that all aspects of the assessment are appropriate. According to Shrotryia and Dhanda (2019), the e-Module has good and excellent content validity, with the minimum S-CVI value being 0.80. The researcher has considered all written comments from the expert panel to improve the e-Module. The experts suggested providing clearer instructions for e-Module users, such as specific user notes for teachers and students. It was also suggested that assessment through learning activities in the e-Module should be clarified. Additionally, experts suggested conducting discussion sessions to build FILA charts using platforms like Google Meet, Zoom, Webex, etc., compared to the original platform which only used Google Forms to collect FILA charts.

Language Validity

A language validation process was conducted on the PBL Chemical Equilibria e-Module by a language expert who is a Specialist Teacher for the Malaysian University English Test (MUET) STPM from the MUET Unit, Form Six Center. The expert holds a doctorate in teaching English (TESOL). The language validation process is crucial to review, correct, and enhance the use of language in the PBL Chemical Equilibria e-Module, making it more accurate and suitable for the target user. The language expert provided comments, including corrections to spelling, grammar, capitalization, and punctuation. Based on these comments, certain sections in the e-Module have been modified and improved to help users understand the intended meaning.

VI. DISCUSSION

This study has outlined the five stages involved in developing the PBL Chemical Equilibria e-Module using the ADDIE model. The results of the study showed that the average validity for each item (I-CVI) is above 0.80, with an overall S-CVI value of 0.96. This indicates that the e-Module has good content validity. The Content Validity Index is a commonly used method in quantitative assessment, and it provides a comprehensive analysis of data collected for module validity. This method is practical because it is easy to administer, low-cost, time-saving, and easy to implement. Other studies, such as the development of the PRO-STEM Module by Kasim and Che Ahmad (2018), have also used the same analysis to measure the validity of the module's content.

Content Quality

The e-Module aims to help form six students understand chemical equilibria and enhance their HOTS by exposing them to real-world problems. After assessing the learning objectives, experts agree that they are clear and achievable through teaching activities and strategies. They believe that the objectives align with the goals of the e-Module and lead to the attainment of learning outcomes. However, expert E5 raises a concern about the compatibility of the learning objectives with the proposed activity and assessment for item 3. Four other experts strongly agree that the stated objectives align with the proposed activities and assessment. To address this issue, the researcher has provided more details on the problem scenarios and what students need to study.

Next, the validation of the e-Module content involves items 6 to 10. All experts agree that items 6, 7, and 10 comply with the stated learning objectives, are complete in terms of teaching steps, and do not conflict with the values of society. However, expert E5 did not express agreement or disagreement with items 8 and 9, which state that the content of the e-Module is complete in terms of reinforcement training and assessment. E5 commented that the exercise section does not use the FILA chart, while the purpose is for PBL skills. To improve the module, the researcher has prepared a lesson plan to explain the use of FILA charts in the PBL process.

Effectiveness Potential

The evaluation of the potential e-Module's effectiveness has been analyzed based on usability, flexibility, performance, and assessment. The usability aspect of the e-Module comprises items 11-15, which include complying with learning objectives, teaching steps, reinforcement training, assessment, and e-Module content that aligns with community values. Analysis indicates that all experts agree with items 11, 12, and 15. However, expert E5 has neither agreed nor disagreed with items 13 and 14 and has not provided any comments. This suggests that the e-Module has a good level of usability.

The assessment of the flexibility aspect involves items 16-20. To assess this aspect, we analyzed whether the e-Module's content can be used for teaching and self-learning purposes, whether the difficulty level is appropriate for students' cognitive abilities, whether the activities suggested in the e-Module improve higher-order thinking skills (HOTS), and whether the teaching methods challenge students' HOTS. All experts agree with items 18, 19, and 20. However, expert E5 neither agrees nor disagrees with items 16 and 17, stating that there should be a usage note for teachers and students. Therefore, we have prepared two versions of the e-Module - one for teachers and one for students - to improve the module.

According to the analysis of the effectiveness potential validity, specifically on items 21-25, the e-Module has good performance validity as all experts agreed with the tested items. The validity of this section indicates that the e-Module's scope and sequence of topics are suitable for students' development needs. It is also organized logically and coherently by the order of learning. The allocated time for planned activities is appropriate, and the use of teaching media such as videos, simulations, diagrams, and others is appropriate. Additionally, the terms used in the e-Module are easy to understand.

According to the assessment aspect's effectiveness potential validity analysis, all the experts agree with items 26, 27, 29, and 30. This indicates that the e-Module has good validity because the experts agree that the teaching strategy aligns with the 5 steps and the PBL Model, the assessment of students is compatible with the e-Module content, and the given assessment can measure the level of learning objectives' achievement. However, expert E5 did not agree or disagree with item 28, which states that assessment can be carried out through learning activities in the e-Module by giving uncertain comments because students only need to submit answers. As an improvement, the researcher has detailed in the prepared lesson plan that the teacher will check all student answers and responses and discuss them with the students.

Overall Satisfaction

The e-Module's content validity regarding overall satisfaction was evaluated based on items 31 - 45. The analysis results indicate that this e-Module has excellent content validity. All of the experts have agreed with almost all of the evaluated items. However, expert E5 neither agreed nor disagreed with item 31. This is because the purpose of the module was unclear to her, and she provided an uncertain comment about whether the module was intended for teachers or students. As a result, the PBL Chemical Equilibria e-Module has been improved by creating a teacher's version and a student's version. The teacher's version contains complete answers for all activities planned in the e-Module.

VII. CONCLUSION

Experts have concluded that the e-Module on Chemical Equilibria is a suitable resource for form six students looking to enhance their higher-order thinking skills (HOTS). The e-Module's problem-based learning (PBL) model is seamlessly integrated with clearly defined objectives, appropriate language, easily understandable content, and practical learning techniques that promote student autonomy in the Chemistry class. The e-Module has a high average item content validity score (S-CVI) of 0.96, with each item's I-CVI value exceeding 0.80, indicating its reliability. PBL is a student-centered learning method that helps students connect scientific concepts with real-life scenarios. With this e-Module, form six students are expected to gain a better understanding of chemical equilibria concepts and develop problem-solving skills to tackle real-world problems. The e-Module is expected to be widely used in the teaching and learning of chemistry to help students develop positive attitudes towards learning chemistry and improve their social skills during group learning sessions. The PBL approach may pose some challenges, but it is highly effective in cultivating the necessary knowledge, skills, and values that align with the needs of the 21st century.

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