

Creating and Implementing a Website Using the Representation Learning Cycle (RLC) Model: An Effort to Enhance Understanding of Chemical Concepts and Representations in Chemical Equilibrium

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Abstract: This study investigates the challenges students encounter when trying to comprehend abstract concepts in chemistry, with a primary focus on chemical equilibrium. The research aims to develop and implement website-based teaching materials grounded in the Representation Learning Cycle (RLC) model to enhance students' comprehension of chemical concepts and representations. Employing the ADDIE development model—consisting of analysis, design, development, implementation, and evaluation—the study utilises a quasi-experimental method with a nonequivalent control-group design. The effectiveness of the teaching materials is assessed through pretest and posttest measures of students' understanding. Results indicate that the developed website-based materials are feasible, achieving a validator test score of 92.5% and a readability score of 96.3%, both categorised as very feasible. The N-Gain Score of 0.69 suggests a sufficient level of effectiveness, while the Mann-Whitney Test yielded a result of 0.02, below the significance threshold of 0.05. Consequently, it can be concluded that the developed teaching materials significantly enhance students' understanding of chemical concepts and representations.

Keywords: Website; Representation Learning Cycle; Concept Understanding; Chemical Representation; Chemical Equilibrium

INTRODUCTION

Chemistry is a crucial field of science intricately connected to everyday phenomena. However, students often find abstract concepts in chemistry challenging to grasp. Research indicates that students are deemed to have understood a concept when they can attribute meaning to it (Mason et al., 1997). Learning success is significantly influenced by students' mastery of concepts, as those who struggle to comprehend foundational ideas often face difficulties when encountering more advanced topics (Stefani & Tsaparlis, 2009). In chemistry, understanding extends beyond mere abstraction, encompassing algorithmic and conceptual comprehension. Conceptual understanding pertains to the meaning, content, theory, and explanation of chemical phenomena, while algorithmic understanding involves applying mathematical processes through a series of rules (Pak et al., 2001). Integrating conceptual and algorithmic understanding is essential for a comprehensive grasp of chemical concepts (Bruck et al., 2009).

The comprehension of abstract chemical concepts can be facilitated through chemical representations. Chemical representation encompasses various forms of information, including text, images, graphs, videos, and tables, which collectively aid students in better understanding specific chemical concepts (Freitas, 2023). These concepts can be categorised into three types of chemical triplet representations: macroscopic, sub-microscopic, and symbolic (Su, 2016). The study of chemistry inherently involves these three representations. For instance, observable phenomena at the macroscopic level can be analysed from a sub-microscopic viewpoint, focusing on atoms and molecules, and subsequently translated into symbolic representations using chemical symbols, formulas, and reaction equations (Moulton & Zaworotko, 2001). This interconnectedness

underscores the necessity for students to develop a robust understanding of chemical representations to achieve a profound comprehension of chemical concepts (Níaz, 1995).

Chemical equilibrium is a complex chemistry education topic encompassing these three representations (Chiu et al., 2022). The abstract nature of this concept often poses challenges for students, necessitating the use of representations to facilitate understanding (Sari, 2023). In the context of chemical equilibrium, conceptual understanding includes the notion of dynamic equilibrium. In contrast, algorithmic understanding pertains to calculating equilibrium constants and interpreting equilibrium diagrams and graphs. Research has shown that students frequently struggle with the material related to chemical equilibrium, particularly in understanding dynamic equilibrium and the factors influencing it (Cheung, 2011). The difficulties students face can be attributed to the ineffectiveness of traditional learning resources, as many educators continue to rely on lecture-based methods and standard teaching materials, which may not adequately support the comprehension of complex chemical representations (Nakıbođlu & Yildirir, 2011).

To tackle these challenges, the author proposes an innovative approach through the Representation Learning Cycle (RLC) model, utilising website media as a teaching tool. The RLC model comprises six phases: orientation, question posing, planning, execution, analysis, and *presentation of findings* (Herunata, 2016). Many existing educational websites present material in a disorganised manner, which leads to student disengagement. Therefore, a structured learning model is essential to guide students effectively through the learning process. The RLC model, previously developed for printed teaching materials, will be adapted for online use to enhance student engagement and comprehension in the context of chemical equilibrium (Gültepe et al., 2013). The integration of website-based teaching materials has been shown to improve learning outcomes in chemistry, as research indicates that such resources can significantly enhance students' understanding of chemical concepts (Phelps et al., 1997). The RLC model aims to facilitate the learning process by providing a clear framework for students to navigate through the various levels of chemical representation, thereby promoting a deeper understanding of the material (Zoller & Tsaparlis, 1997).

The objectives of this research are twofold: firstly, to develop website-based teaching materials focused on chemical equilibrium using the RLC model, and secondly, to evaluate the effectiveness of these materials in enhancing student learning outcomes. The RLC model comprises six phases: orientation, question posing, planning, execution, analysis, and presentation of findings (Fitriani et al., 2022). By implementing this model, the research aims to create a more engaging and effective learning environment for students studying chemical equilibrium.

METHOD

This research employs the Research and Development (R&D) method to create teaching materials in the form of a website, utilising the Representation Learning Cycle (RLC) model. The ADDIE model, consisting of five stages—(1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation—is used for this R&D study (Branch, 2009). The methodology of this research is divided into two primary components: development and implementation. The website's development encompasses the analysis, design, and development stages, while the implementation stage focuses on deploying the website products. The evaluation stage is incorporated into each phase to assess the effectiveness of the processes undertaken. A detailed explanation of the research stages is provided below.

Development of teaching materials in the form of a *website* with a Representation Learning Cycle Model (RLC) on Chemical Equilibrium Material

The ADDIE method was used in the analysis, design, and development stages of this teaching material.

Analysis

During the analysis stage, the researchers conducted a thorough assessment of the needs of both students and teachers while also analysing the materials related to chemical equilibrium. They undertook a literature review, drawing from relevant books and previous studies related to the research topic. This literature review aims to establish a theoretical foundation that bolsters the researchers' efforts in enhancing the credibility of their study. Furthermore, the evaluation stage is applied at each phase to assess the effectiveness of that stage before progressing to the next one.

Design

During the design stage, the researchers prepare teaching materials in the form of a website, adhering to the planned design and format. They create a storyboard for the product being developed, which serves as a tool in website design, assisting in the planning and visual representation of page layouts, navigation, and content before commencing the full development process. To create the website, the researchers utilise the Google Sites platform. Additionally, applications such as Canva are employed to design the content that will be integrated. Subsequently, a design evaluation is conducted to assess the materials and determine their readiness to proceed to the next stage.

Develop

At this stage, the researcher has developed a website centred on chemical equilibrium materials, utilising the Representational Learning Cycle model. Additionally, the resources will be validated by subject matter experts, including expert lecturers, media specialists, and chemistry teachers. The validation process involves evaluations by media experts that assess visual appearance, images, videos, and usability. Following this, validation by chemistry education experts will focus on material and content aspects, presentation elements, and linguistic considerations. Furthermore, validation will also be carried out on assessment instruments (Pretest and Posttest) and teaching modules. Subsequently, a product readability test will be administered to students to evaluate the teaching materials from their perspective.

Data analysis will encompass both quantitative and qualitative data. Qualitative data will include notes, suggestions, and comments from the validation questionnaire assessments, which will be used for data analysis. In contrast, quantitative data will be employed to process the results from the validation tests and the website readability using the following formula:

$$\text{Percentage}(\%) = \frac{\text{score obtained}}{\text{maximum score}} \times 100\%$$

The validity and readability criteria *for the website* are shown in Table 1

Table 1. Website Validity and Readability Criteria

Percentage	Category
$75\% \leq P \leq 100\%$	Valid/very good
$50\% \leq P < 75\%$	Fairly valid/good
$25\% \leq P < 50\%$	Invalid/not good
$0\% \leq P < 25\%$	Invalid/not good

(Saraswati et al., 2019)

The readability and validation test results will become a benchmark for revising learning media. At this stage, the evaluation stage is used to improve according to suggestions/comments from the validation results, and then it can be continued to the next stage.

Implementation in learning using teaching materials in the form of a *website* with a Representation Learning Cycle Model (RLC) on Chemical Equilibrium Material

After completing *the analysis, design, and development stages*, we move on to the *implementation stage*, which involves applying learning materials and strategies designed by researchers to students.

Implement

Websites that have been validated and deemed suitable are subsequently employed in the learning process to evaluate their impact on student comprehension. The fourth stage is implementation, which uses a quasi-experimental method featuring a non-equivalent control group design. This implementation comprises three phases: conducting an initial assessment to evaluate students' baseline abilities, integrating the website into the learning process, and administering a final assessment to gauge students' abilities following the intervention. Additionally, student response questionnaires are distributed to collect feedback regarding their experiences with the website-based learning. The application of teaching materials in a website is designed for both experimental and control groups. The design can be elaborated on in Table 2.

Table 2. Quasi Experimental Nonequivalent Control Group Design

<i>Class</i>	<i>Pre-Test</i>	<i>Treatment</i>	<i>Post-Test</i>
Experiment	O ₁	X ₁	O ₂
Control	O ₃	X ₂	O ₄

Source: Creswell, 2012

X₁ = Treatment of using the chemical equilibrium *website* with the RLC model

X₂ = Treatment without chemical equilibrium *website with the RLC model*

O₁ = Initial ability test in the experimental class

O₂ = Final test in the experimental class

O₃ = Initial ability test in the control class

O₄ = Final test in the control class

The research was conducted at a high school in Malang during February of the 2023/2024 academic year. The sampling method employed was convenience sampling. The population consisted of all students in the XI Science classes at the high school. Specifically, two XI Science classes were selected as samples: XI Science Class 1 served as the experimental group, while XI Science Class 3 functioned as the control group. The instruments utilised in this study included both treatment and measurement tools. The treatment instruments comprised teaching modules and a website based on the Representation Learning Cycle (RLC) model, which were validated by a chemistry lecturer from Universitas Malang (UM) and a teacher. The measurement instruments consisted of test items, specifically Pretest and Posttest questions. Two validators confirmed these questions: one chemistry lecturer from UM and one chemistry teacher. The questions underwent a validation process during the development stage. Data collected from the implementation phase included the results of the Pretest and Posttest, which will be analysed both statistically and descriptively. The statistical analysis aims to identify differences in understanding between the classes that utilised the website and those that did not. The first test conducted is the prerequisite test, which includes:

Normality Test

The Normality Test is used to determine whether the data is normally distributed or not. Normality test using *SPSS 26.0 for Windows*, with the following criteria.

- If the significance is > 0.05 , it means the data is normally distributed
- If significance < 0.05 , it means the data is not normally distributed

Table 3. N-Gain Score Criteria

N-Gain Value	Category
$g > 0.70$	Tall
$0.30 \leq g \leq 0.70$	Currently
$g < 0.30$	Low

(Sugiyono, 2006)

Homogeneity Test

The homogeneity test was conducted to determine whether the two samples came from the same population. Homogeneity test using the *SPSS 26.0 for Windows program*, with the following criteria

- If the significance is > 0.05 , it means the sample is homogeneous
- If the significance is < 0.05 , it means the sample is not homogeneous

After carrying out the prerequisite tests according to the description above, a hypothesis test is carried out using the Mann-Whitney U Test if the data is not normally distributed and homogeneous. Here are the rules for this test.

- If the Asymp.Sig value < 0.05 , it means that H_1 is accepted
- If the Asymp.Sig value is > 0.05 , it means that H_1 is rejected

The hypothesis tested in this research is H_1 : There is a difference in understanding between classes that use *websites* and those that do not. A descriptive analysis is employed to assess students' understanding of post-learning chemical equilibrium material via *the website using the N-Gain Score test*. Below is the formula for *the N-gain score*:

$$N\ GAIN = \frac{\text{posttest score} - \text{pretest score}}{\text{ideal score} - \text{pretest score}}$$

The *N-gain core values*, calculated according to the formula above, will then be grouped according to their effectiveness levels, as shown in Table 3. Table 4 shows the stages of this research.

Table 4. Addie Method Development and Research Stages

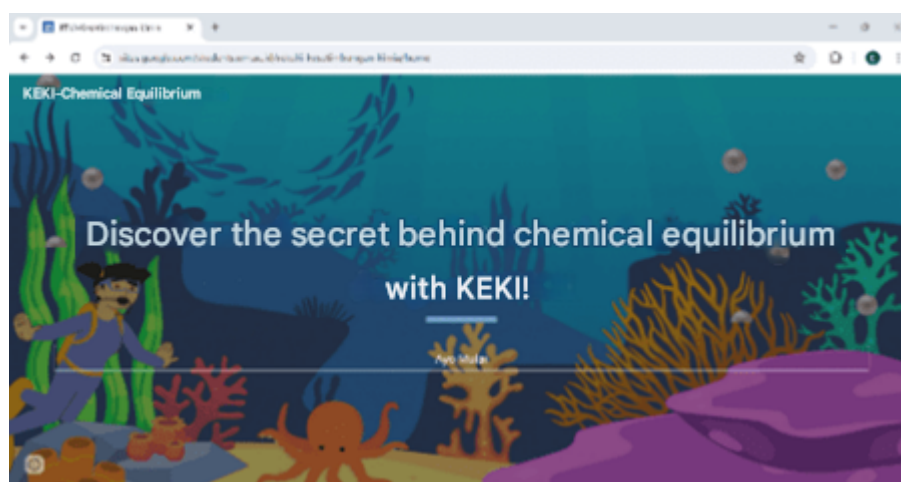
No	Stages	Activity	Instrument
1	<i>Analysis</i>	- Analysis of student needs - Analysis of teacher needs - Evaluation analysis stage	- Student needs questionnaire sheet - The teacher needs an interview questionnaire sheet
2	<i>Design</i>	- Create a <i>Storyboard</i> with <i>Canva</i> - <i>Website</i> design using <i>Google Sites</i> - Evaluation of the design stage	
3	<i>Develop</i>	- Media validation test (teaching materials) - Validation test of the test question instrument - Test students' readability - Evaluation of the develop stage	- Media validation questionnaire sheet - Test question instrument validation questionnaire sheet - Student readability test sheet
4	<i>Implement</i>	- Distribution of <i>Pretest questions</i> - Application of teaching materials in the form of <i>websites</i> in classroom learning - Distribution of <i>Posttest questions</i> - Filling out student response questionnaires	- Question instrument - Student response questionnaire sheet

RESULTS AND DISCUSSION

Results of Developing Teaching Materials in the form of a Website with a Learning Cycle Model of Representation in Chemical Equilibrium Material

Product description in the form of a website with a Representation Learning Cycle Model in Chemical Equilibrium Material

This research has produced a set of teaching materials centred on chemical equilibrium, presented as a website that employs the Representational Learning Cycle (RLC) learning model. Users can access these teaching materials online free of charge. The website encompasses a range of resources, including images, audio, video, instructional content, and practice questions. Named 'KEKI', which stands for 'Chemical Equilibrium', the website includes several menus: a start page, a menu page, and a contents page.



Link: <https://sites.google.com/students.um.ac.id/keki-kesetimbangankimia>

Figure 1. Interface of Keki Websites

The start page offers concise information about the topics to be studied and features an engaging invitation to capture website visitors' attention. The website's background includes moving animations designed to enhance readers' interest in learning about chemical equilibrium. After the start page, users are directed to the "Background" menu, which seeks to help them comprehend the rationale and objectives behind the "KEKI" website. Following this, users are taken to the login page. Once students input their username and password, they are redirected to the menu page, which comprises six sections: navigation instructions, concept map, learning model, learning outcomes (CP), learning objectives (TP), equilibrium learning, and developer profiles.

On the menu page, the first section, navigation instructions,

The third section is the 'Learning Model' menu, which explains the model applied on the KEKI website, specifically the Representation Learning Cycle Model (RLC). This page provides a detailed explanation of the RLC model's syntax, ensuring that users understand the learning flow of the website. The fourth section, 'Learning Achievements (CP) and Learning Objectives (TP),' contains descriptions of the expected learning outcomes and objectives aligned with the Independent Curriculum. This section informs users of the goals and achievements anticipated in their understanding of chemical equilibrium.

The fifth section features a profile page that includes the developer's biodata, such as their identity, photo, and agency name. It also provides a list of references used to prepare the teaching materials on the website. The sixth section is dedicated to Chemical Equilibrium Learning, serving as the website's core page.

The website's main page features the "Chemical Equilibrium Learning" menu, organised into four meetings corresponding to the sub-chapters of chemical equilibrium material. Meeting 1 covers the topic of dynamic equilibrium; Meeting 2 addresses equilibrium constants; Meeting 3 discusses factors that influence chemical equilibrium, and the final meeting consists of practice questions designed to assess understanding of the chemical equilibrium content. Each meeting is structured into several stages that align with the syntax of the Representation Learning Cycle (RLC) model, which includes orientation, question posing, planning, execution, analysis, and presentation of findings.

Product Validation Test Results in the form of a Website with a Representation Learning Cycle Model in Chemical Equilibrium Material

After developing the product, the next stage involves validating it with one chemistry lecturer and one chemistry teacher. The validation assessment data collected from the validators includes both qualitative and quantitative components. The qualitative data comprises comments and suggestions from the validators to enhance the website's teaching materials. In contrast, the quantitative data is represented by scores assigned by the validators to these materials. Suggestions and comments regarding the website's teaching materials are presented in Table 7, while the validator score assessment data is displayed in Table 5.

Table 5. Keki Website Development Validation Results

No	Assessment Aspects	%	Criteria
1	Keki <i>website</i> appearance	87.5%	Very worthy
2	Keki <i>website</i> presentation	92.5%	Very worthy
3	Language eligibility	98%	Very worthy
4	The relevance of the material to understanding chemical concepts and chemical representation	92%	Very worthy
Average		92.5%	Very worthy

The validation results in the table show an average of 92.5%, which means the product produced is valid and feasible (Saraswati et al., 2019). The qualitative data are in Table 6.

Table 6. Results of Validation of Keki Website Qualitative Data Development

No	Website section	Suggestion
1	Home	In the front <i>layout</i> , instructions/titles are provided regarding the teaching materials being developed and the learning model
2	Instructions for use	The learning access flow is described in detail
3	Core activities	Discussion of the questions is locked first
4	<i>Execute</i> (First Meeting)	Questions are clarified further and YouTube videos can be added with translations
5	<i>Orientation</i> (Second Meeting)	The font size is the same
6	Core activities	The material is given audio and summarized
7	Home	Added background for developing <i>website teaching materials</i>

Based on the qualitative data in the table above, several suggestions/inputs from validators exist. These suggestions are used as a reference for revising *the website's teaching materials*. The *website* teaching materials have been validated and then revised, followed by carrying out readability tests on students.

Product Readability Test Results in the form of a Website with a Representation Learning Cycle Model in Chemical Equilibrium

After carrying out validation and revision tests, the next stage is to carry out readability tests on students. Readability test data includes two, namely quantitative data and qualitative data. Quantitative data is obtained from student score assessments, while qualitative data is in the form of suggestions/comments from students. Readability test data is in the form of a questionnaire

filled out by students. The results of the quantitative data can be seen in Table 7.

Table 7. Readability Test Results by Students

No	Aspect	%	Criteria
1	Frontpage (home) of the Chemical Equilibrium <i>website</i>	98%	Very Worth It
2	The layout on each page is appropriate and clear	94%	Very Worth It
3	The language used is clear so it is easy to understand	96%	Very Worth It
4	The choice of font and color composition is correct	94%	Very Worth It
5	Instructions for use make it easier for me to use <i>the website</i>	96%	Very Worth It
6	The menu page looks clear and structured	98%	Very Worth It
7	The material is presented in a way that is easy to understand and clear	98%	Very Worth It
8	Content that involves images and videos that are relevant to the material being presented	98%	Very Worth It
9	<i>website</i> makes chemical equilibrium material fun	90%	Very Worth It
10	The questions on <i>the website</i> can increase my understanding of chemical equilibrium material	98%	Very Worth It
11	<i>The links</i> and filling in answers on <i>the website</i> are easy to use	98%	Very Worth It
12	The existence of the "KEKI" <i>website</i> helped me to learn about chemical equilibrium material	98%	Very Worth It
Average		96.33%	Very Worth It

By referring to the results of testing students' readability in Table 7, an average of 96.33% was obtained, which means it is feasible (Saraswati et al., 2019). After the readability test, implementation was carried out using the *Keki website teaching materials*.

Application of Learning using the Representation Learning Cycle Model (RLC) Website on Chemical Equilibrium

Description and Analysis of Student Ability Data

Learning activities are conducted after students' readability is tested. Before these activities, students' initial abilities in both classes are analysed. Based on the students' pre-test results, students' initial understanding is *measured*. *The pretest and posttest* score data from both classes are as follows.

Table 8. Description of Pretest and Posttest Results for Control Class and Experimental Class

Class	Number of Students	The highest score	Lowest Value	Mean	Standard Deviation
Experimental Class (Pretest)	30	45	40	42.47	1,432
Experiment Class (Posttest)		100	55	82.37	9,231
Control Class (Pretest)		43	31	39.33	3,517
Control Class (Posttest)		100	44	74.60	13,546

The prerequisite tests are conducted, specifically the tests for homogeneity and normality, using *SPSS 26.0 for Windows* to assess both. The normality test uses *the Shapiro-Wilk calculated value*; if this value is greater than 0.05, then the data is considered to be normally distributed. The results of the normality test can be found in Table 9.

Table 9. Normality Results of Pre-Test and Post-Test Results for Control Class and Experimental Class

Class	Count Value (<i>Shapiro-Wilk</i>)	Level of Significance	Test Decision
Experimental Class (pretest)	0.044	0.05	Abnormally Distributed
Experiment Class (posttest)	0.086	0.05	Normally Distributed
Control Class (pretest)	0,000	0.05	Abnormally Distributed
Control Class (posttest)	0.154	0.05	Normally Distributed

Table 9. Homogeneity Test Result

Variable	Calculate Value	Significance Level	Test Decision
Experiment-control	0.067	0.05	Homogeneous

Based on the data in Table 11, the calculated value is 0.067, indicating that the result exceeds 0.05. Therefore, it can be concluded that the sample is homogeneous. The subsequent test is the *Mann-Whitney Test*, with results in Table 11.

Table 10. *Mann-Whitney Test* Statistical Test Tabl

Class	Number of Students	Test Results <i>t</i> (sig. (2-tailed))
Control	30	0.022
Experiment	30	

Table 12 illustrates that the T-test results yield a value of 0.022, less than 0.05. This indicates that the null hypothesis (H₀) is rejected, and the alternative hypothesis (H₁) is accepted, leading to the conclusion that there is a significant difference between the abilities of the experimental and control group. The next test was the N-Gain Score test to assess the achievement of student learning outcomes before and after being given learning using teaching materials in the form of a *website*. The N-Gain test results can be seen in Table 12.

Table 11. N-Gain Test Results

N -Gain indicator	N -Gain value
Student learning outcomes	0.69

From the N-Gain results table, the result is 0.69. This is compared with Table 2 of the *N-Gain* Score Criteria in Table 4. The conclusion is that using teaching materials on *websites* with the Representation Learning Cycle (RLC) learning model is quite effective.

Results of Data Analysis on Implementation of Learning with the Representational Learning Cycle Model Website

Before instruction begins, the teacher develops a teaching module based on the lesson plan for the class. The lesson is divided into three meetings: meeting one covers dynamic equilibrium, meeting two pertains to equilibrium constants, and meeting three addresses factors that influence chemical equilibrium.

Description of Learning on the Keki Website:

Meeting 1

During the first meeting, we focused on the topic of dynamic equilibrium. The learning process commenced with students completing pre-test questions to assess their initial abilities. Following this, instruction utilised the Representational Learning Cycle (RLC) model, incorporating the Keki website's teaching materials. The learning began by presenting students with an apperception in the form of a problem, accompanied by representations of phenomena such as melting ice, combustion, and heating water. Students were then encouraged to formulate

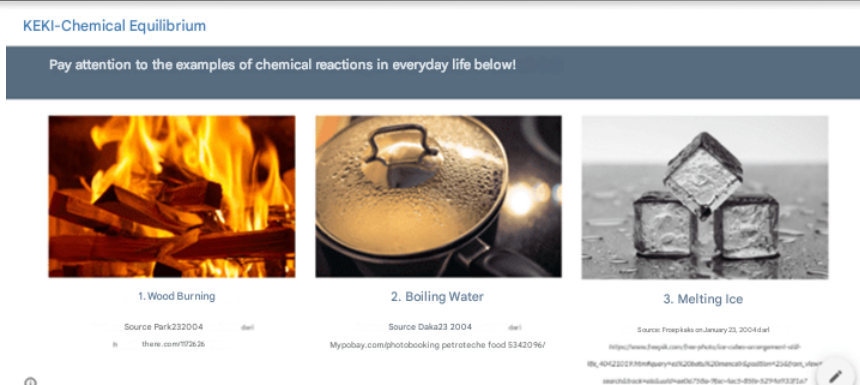


Figure 2. Orientation Menu at Meeting 1 Keki Website

Next, the researcher instructed students to form groups consisting of 3 to 5 members. Students were then directed to discuss their investigations based on reliable sources and to read the material available on the Keki website. After understanding the material, they proceeded to the "execute" stage, where students received instructions to complete the questions in the execute menu on the Keki website. The questions were answered collaboratively within the groups and subsequently discussed among peers. The teacher's role in this process was to support students who were still unclear about the meaning of the questions. The questions in this research were descriptive, facilitating a conceptual investigation. Each group then presented their responses to the questions in the execute menu. The audience group was encouraged to provide suggestions, comments, or questions to the presenters. The teacher's role during this presentation process was to assist students and correct any inaccuracies in their answers. The results of the presentations were then collectively agreed upon as a comprehensive conclusion. Students were encouraged to ask the teacher for clarification if they did not understand the material. The final step, "present findings," involved students completing additional questions on the Keki website to reinforce their understanding.

Meeting 2

At the second meeting, we discussed the equilibrium constant. Learning begins with an apperception for students by showing a data table of experimental results from the reaction $\text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g)$. Then, students are directed to raise questions about the table, such as "How do we assess the concentration ratio when a reactant or product consists of more than one compound?" "In the table above, which value is constant?"

KEKI-Chemical Equilibrium

The table below is the experimental data from the reaction.
 $\text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g)$

[N ₂ O ₄]		Equilibrium Concentration		Comparison of Concentrations at Equilibrium	
[NO ₂]	[N ₂ O ₄]	[NO ₂]	[N ₂ O ₄]	$\frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]}$	$\frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]}$
0,000	0.670	0.0547	0.643	0.0851	$4,65 \times 10^{-3}$
0.0500	0.446	0.0457	0.448	0.102	$4,66 \times 10^{-3}$
0.0300	0.500	0.0475	0.491	0.0967	$4,60 \times 10^{-3}$
0.0400	0.600	0.0523	0.594	0.0880	$4,60 \times 10^{-3}$
0,200	0,000	0.0204	0.0898	0.227	4.6

Table 1. NO₂, N₂O system at 25°C

Figure 3. Menu Orientation Meeting 2 Keki Websites

Subsequently, the teacher instructs students to form groups and engage in discussions for conducting investigations. Students are encouraged to seek learning resources from reliable

sources, such as eBooks, printed books, and reputable websites that offer relevant collections of materials. After reviewing and discussing the content, students are directed to complete the questions in the execution section. They are expected to differentiate between K_c and K_p and calculate the equilibrium constant. The results from the execution section are presented solely by designated representatives from each group. Audience members are invited to respond, ask questions, and provide feedback. In this context, the teacher's role is to facilitate the presentation and correct inaccuracies when they arise. If any questions remain unclear, students are encouraged to seek clarification from the teacher. The final stage of this learning process involves students practising by working on questions related to their findings, which serves to enhance their understanding.

Meeting 3

In Meeting 3, we discussed the factors that influence chemical equilibrium. The learning process began with an apperception activity where students observed an image depicting a seesaw event. Students were then encouraged to pose questions such as, "What influences chemical equilibrium?" Following this, they were directed to consult reliable literary sources to conduct their investigations. These sources included eBooks, online resources, printed books, and reading materials on the Keki website. Once students had grasped the material, they were instructed to work on questions during the "execute" stage while engaging in group discussions. Representatives from each group subsequently presented the results of their discussions. The audience was invited to provide the presenters with objections, comments, suggestions, and questions. The teacher's role in this context was to facilitate a conducive presentation environment and to offer guidance on correct answers in the event of conceptual errors. Students were encouraged to ask the teacher questions if they found any material unclear. The lesson concluded with students independently working on questions in the "present findings" section, which aimed to broaden their understanding.

Description of Understanding Chemical Concepts and Representations in Chemical Equilibrium

The post-test results administered to students reflect their understanding of chemical concepts and representations related to chemical equilibrium. These findings are further supported by observations of the learning implementation tailored to the developed teaching modules. In chemistry education focused on chemical equilibrium, the researchers utilised web-based teaching materials to elucidate the various levels of representation: macroscopic, submicroscopic, and symbolic. It is anticipated that the descriptions provided on the website will enhance students' comprehension of the material related to chemical equilibrium. The students' post-test results were analysed and are presented in Table 13.

Table 13. Results of Student Concept Representation and Understanding Percentage

Representation	Criteria		Number of Students (%)	
	Concept Understanding		Experimental Class	Control Class
Correct	Correct	60%	46.67%	
Correct	Wrong	23.3%	16.67%	
Wrong	Correct	16.7%	36.67%	
Wrong	Wrong	0%	0%	

The results of the student post-test were subsequently analysed and categorised into four distinct groups. The first category represents a correct understanding of concepts with accurate representation (BB); the second category denotes correct representation but an incorrect understanding of concepts (BS); the third category indicates misrepresentation despite a correct understanding of concepts (SB); and the fourth category signifies both misrepresentation and incorrect understanding of concepts (SS). The BB category, which reflects correct representation and accurate understanding of concepts, exhibited the highest percentage in both classes, with

60% in the experimental group and 46.67% in the control group. This finding suggests that most students in both classes possess correct representations and a solid understanding of concepts related to chemical equilibrium. In the BS category, which represents correct representation but incorrect understanding of concepts, the experimental group achieved a percentage of 23.3%, surpassing the control group, which recorded only 16.67%. This

Table 14. Results of Representation and Understanding of Concepts Seen from Sub-Material

Class	Dynamic Equilibrium				Equilibrium Constant				Factors affecting chemical equilibrium			
	BB	BS	SB	SS	BB	BS	SB	SS	BB	BS	SB	SS
Experimental Class	15	11	4	0	9	15	6	0	19	11	0	0
Control Class	10	9	11	0	10	11	9	0	17	13	0	0

Information:

BB = Correct representation and correct understanding of concepts

BS = Correct representation and incorrect understanding of the concept

SB = Incorrect representation and correct understanding of the concept

SS = Incorrect representation and inaccurate understanding of the concept

Table 14 presents the results regarding students' representation and understanding of concepts across three sub-materials. The data indicate that for the sub-materials of dynamic equilibrium and shifting equilibrium, the experimental group surpassed the control group in both correct representation and accurate conceptual understanding (BB). Conversely, in the sub-material concerning equilibrium constants, the experimental group had a greater number of students classified in the BS category (correct representation but incorrect understanding of the concept) compared to the control group.

In the dynamic equilibrium sub-material, the experimental group benefited from website-based teaching resources that provided chemical visualisations of dynamic equilibrium, enhancing students' comprehension of this topic. Notably, there were no representation errors in the sub-material addressing factors that influence chemical equilibrium for either the experimental or control groups, indicating that students demonstrated a solid understanding in this area. However, students in both the control and experimental groups were still categorised as SB and BS in the equilibrium sub-material. This occurrence may be attributed to the fact that the equilibrium constant involves mathematical calculations and an understanding of the relationship between the concentrations of reactants and products in an equilibrium state. Students may struggle to comprehend the mathematical equations used to calculate K_c and K_p , particularly if they lack a strong mathematical foundation.

Question Analysis

Question 6 addresses the impact of temperature on chemical equilibrium. If the temperature increases, the equilibrium shifts towards an endothermic reaction; conversely, if the temperature decreases, the equilibrium moves towards an exothermic reaction. In this problem, the influence of temperature is illustrated through molecular representations in pictures. When the system is immersed in hot water, the quantity of product molecules exceeds that of the reactants, indicating that the equilibrium favours the products. In contrast, when the system is placed in ice water, the number of reactant molecules surpasses that of the products, suggesting that the equilibrium favours the reactants.

QUESTION

Look at the picture below!
The image below is an example of a reaction that occurs due to the influence of temperature which causes a shift in equilibrium. The reaction equation is as follows.

$$\text{Co}(\text{H}_2\text{O})_6^{2+}(\text{aq}) + 4\text{Cl}^-(\text{aq}) \rightleftharpoons \text{CoCl}_4^{2-}(\text{aq}) + 6\text{H}_2\text{O}(\text{l})$$

(A) Condition at room temperature

(B) The condition when the solution is added to hot water

(C) The condition when the solution is added to cold water

Sumber Gambar : Brown, T. L., Lemay, H. E., Bursten, B. E., Murphy, C. J., & Woodward, P. M. (2012). *Chemistry the central science* (12th ed.). Illinois: Pearson Education, Inc.

The picture shows the effect of temperature on chemical equilibrium. Answer the following questions!

- Figure A is the initial equilibrium state. How many molecules of $\text{Co}(\text{H}_2\text{O})_6^{2+}$ and CoCl_4^{2-} are there?
- In image B (temperature increases), how many molecules of $\text{Co}(\text{H}_2\text{O})_6^{2+}$ and CoCl_4^{2-} are there?
- What is the direction of the equilibrium shift in image B? Explain the reason!
- In image C (temperature decreases), how many molecules of $\text{Co}(\text{H}_2\text{O})_6^{2+}$ and CoCl_4^{2-} are there?

Figure 4. The problem in Keki Websites

Students in the experimental group answered correctly. From points A, B, C, D, and E, one can assess their understanding of chemical concepts and representations in this question. Meanwhile, the control group provided slightly different answers. To interpret the representation, points A, B, and D are correct, although there are still a few inaccurate answers at points C and E. Conceptually, the answer is correct. However, in the context of this question, we still cannot relate to the image representation (the answer pertains to the large quantity of molecules).

CONCLUSION

The research findings encompass the development of teaching materials presented as a website that utilises a Representation Learning Cycle (RLC) model focused on the topic of chemical equilibrium. This educational resource aims to enhance students' understanding of chemical concepts and representations associated with chemical equilibrium. The validation results for the teaching materials yielded an impressive score of 92.5%, categorising them as "very appropriate." Additionally, a student readability assessment achieved a score of 96.33%, also placing it in the "very appropriate" category. Furthermore, a significant difference in students' understanding was observed between the control and experimental groups. The N-Gain Score calculated for the experimental group was 0.69, which falls within the "sufficient" category.

SUGGESTION

Keki websites can be recommended for use in educational units, including Senior High Schools (SMA) or Madrasah Aliyah (MA). Using teaching materials like this *website* has a positive impact on understanding chemical concepts and representations.

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