The making electronic modules visualization chemical equilibrium process based on predict-observe-explain

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Abstract. This study aims to create an e-module visualization chemical equilibrium processes based on POE (Predict-Observe-Explain) which includes sub-concepts of dynamic equilibrium, homogeneous and heterogeneous equilibrium, and factors that influence chemical equilibrium. The three main activities in this e-module are predicting, observing and explaining. The e-module was created using the Design Based Research method with ADD design (Analysis, Design, Development) which was validated by two material expert lecturers and two multimedia expert lecturers producing an overall average calculation of 0.87 while the results of the feasibility test conducted at ten students show a percentage of 98.11%. This shows that this e-module is very feasible to be used as teaching material.

1. Introduction
Chemical equilibrium is one of the topics in chemistry with contains abstract concepts and tends to be difficult to understand [1]. In practically, despite this concept is the basis in learning other chemical concepts, this concept is difficult to teach and has a high level of misunderstanding [2]. One of the factor is caused by the kind of concept which is abstract and has many prerequisite concept [3]. On the other hand, Tasker and Dalton mentioned that one's understanding of chemistry could see from the ability of connecting three levels of chemical representation, that is macroscopic, submicroscopic, and symbolic level [4]. However, in learning, most teachers limit the level of representation in macroscopic and symbolic level, and not connect it with submicroscopic level. Though inability in represents the submicroscopic level can inhibit to solve the problems relating to macroscopic and symbolic level [5].

Along with the growth of technology, in visualizing the submicroscopic level can be use computer as a tool [6,7]. This matter because the molecular world is dynamic moving multiparticles, as well as has complex interactions in solid and liquid phase, so high accuracy in visualization is needed [8]. Kozma and Russell stated that molecular visualization based on computer and integrated three-dimensional animation in learning can help students to have representational ability [9]. In line with that, according to Karpudewan to improve students understanding in chemical equilibrium concept, an alternative teaching strategy needs to be done like using simulations via computer [10]. As for Muntholib in his research revealed that chemical equilibrium teaching material is needed to build the cognitive abilities become long term memory. So the material which can be implemented in chemical equilibrium learning to help students build cognitive abilities is needed [11].

One of the materials learning can be in electronic modules form, which known as e-module. This because e-module can presents the material interactively which displayed by multimedia such as video,
animation, simulation and questions with direct feedback so that information presented is richer compared to print modules [12,13]. One of the main characteristics of e-module according to Depdiknas is self instructional. The characteristic that is capable to make students learn independently without depend on others [14]. Relevant with these characteristics, the POE learning model, with three main activities: (1) predict, (2) observe and (3) give the explanation has a similar purpose to make students can learn independently in problem solving [15]. Other than that Joyce stated POE learning model has an influence to the following: (1) the prediction that have done firstly can help students observe carefully; (2) through that prediction, students will be motivated to find out the answer; (3) through the explanation, students understanding can be known, so the misconceptions that occur can be analyzed; (4) through an explanation of the predictions created before, can help students build new understanding [16]. According to Vavra visualization has a function in helping analyze and solve problems [17], but the development in using it is needed, because students that have studied the visualization tend in a transition state, which is reluctant to leave the previous concept if the new concept they received contrary to what they have known and often fail in transferring what they currently learn into the new situation [7]. So this research aims to describe the display and feasibility of e-module visualization chemical equilibrium process based on POE learning model.

2. Method
The research method used is the Design Based Research method. The development model follows the ADDIE development model which consists of five steps are analysis, design, development, implementation, and evaluation [18]. However, this research was carried out until the development stage because the e-module that was made up until the validation test stage of the expert lecturer and the test was limited to students only, had not been implemented or applied fully in learning.

2.1. Analysis stage
Based on the results of the analysis, this stage produces concept analysis, concept maps, learning indicators and objectives learning, three levels of representation chemical equilibrium concept, content analysis and e-module planning and determining the software for creating e-modules i.e the Lectora 17 application.

2.2. Design stage
This stage consists of creating a flowchart and storyboard that is made with the aim of facilitate reading the contents of the e-module story.

2.3. Development stage
Making e-modules is done at this stage, by combining text, images, videos, animations, simulations and questions with direct feedback systematically and interactively based on the POE learning model. After that the e-module was validated by four validators (two material experts and two multimedia experts), then revised and tested its feasibility to ten chemistry education students who had taken basic chemistry courses.

The validity of an instrument can be known by comparing the feasibility value of the calculation results ($r_{count}$) with critical feasibility ($r_{critical}$) specified [19,20].

3. Results and discussion

3.1. Description of e-module display
Figure 1 shows the instruction display that is intentionally shown after initial display, so users don't have trouble in operating this e-module. In instructions display shown kinds of navigation buttons and descriptions which is equipped with sound instructions served. Navigation buttons used include the main menu button, hint button, sub-material marker button has been completed, the button enable and disable
sound/music, the button to go next page (next button), the button to go to previous page (back button), and the e-module exit button.

![Instruction Display of E-Module](image1)

**Figure 1.** The instruction display of e-module.

Main menu display presented in Figure 2 contains six other menus that are learning objectives, material, evaluation, game, references and compiler profile. All of these menus, can be chosen randomly by the user.

![Main Menu Display of E-Module](image2)

**Figure 2.** The main menu display of e-module.

Display of e-module at sub-material factors that influence chemical equilibrium that begins by predicting what are factors that influence chemical equilibrium by answering click and drag questions that can be seen in Figure 3.
In its delivery, this e-module utilizes visualization of animation, simulation, video, image and other media that contains macroscopic, submicroscopic and symbolic representations, to help users find concepts and solve problems [17] with following POE learning model. This is supported by the statements of Kozma and Rusell that integrating visualization in learning (especially, submicroscopic visualization) can help students have representational abilities [9].

Display of observe activity is shown in Figure 4. Based on predictions before, the user can be compared it with observations at experimental simulations of factors that influence chemical equilibrium. The experiments in the simulation consisted of addition of H\(^+\) and OH\(^-\) concentrations to chromate ion balance, addition or reduction the pressure or volume at chemical equilibrium reaction of formation dinitrogen tetraoxide gas and formation hydrogen iodide gas, and additions or reduction temperature at chemical equilibrium reaction of formation FeSCN\(^2+\) ion and formation CoCl\(^2-\) ion. In this simulation also includes the chemical reaction (as symbolic visualization) for make it easy in use simulation.
Figure 5. Display of explain activity.

Figure 5 show display of explain activity. In this activity there is an animation with macroscopic, submicroscopic and symbolic visualization. This animation visualizes the chemical equilibrium reaction of (a) Fe(SCN)$^{2+}$ (aq) $\rightleftharpoons$ Fe$^{3+}$ (aq) + SCN$^-$ (aq) when added or reduced concentration, (b) bond breaking reaction I$_2$(g) $\rightleftharpoons$ 2I (g) when pressure and volume added or reduced, and (c) N$_2$O$_4$(g) $\rightleftharpoons$ 2NO$_2$(g) $\Delta$H = +57.2 kJ when heated and cooled. On other that, also presented questions to complete the animation with the purpose to guide users in using animation.

Le Chatelier's principle commonly used in predicting the direction of shifting chemical equilibrium is shown at the end, this is intentionally done by adapting inductive learning (from specific to general) so users can conclude themselves through regularities or trends that occur. This is based on the opinion of Devetak which states that good teaching materials have the characteristics of presenting material inductively [21]. On the other hand, through the POE learning model, users are expected to be more active in finding concepts based on analysis and observations which have done [22], so can prove the concept and become meaningful knowledge [23]. This matter supported by the opinion of Joyce that prediction activities are carried out can help users do observation more carefully and be motivated to find out the answer. As well as through explanations activity can help users build their new understanding [16].

Overall, prediction is done by answering apperception questions or predictions of phenomena, observation is done by observing the phenomenon through various media equipped with certain instructions, while the explanation is done by answering a number of questions based on observed phenomena.

3.2. The results of validation and feasibility test

Validation is done by using a questionnaire consist learning aspect, material substance, evaluation, and display and navigation with the aim of knowing the validity of the e-module. Before being tested for its feasibility, the emodule was revised based on suggestions and input from the validator. The results of this validation can be seen in Table 1.

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\text{Table 1. The overall validation result.} \\
\begin{array}{|c|c|c|c|}
\hline
\text{No.} & \text{Rated Aspect} & r_{count} & \text{Critical} & \text{Result} \\
\hline
1. & Learning aspect & 0.88 & 0.30 & Valid \\
2. & Material substance aspect & 0.85 & 0.30 & Valid \\
3. & Display and navigation aspect & 0.86 & 0.30 & Valid \\
4. & Evaluation aspect & 0.87 & 0.30 & Valid \\
\hline
\text{Average } r_{count} & 0.87 & 0.30 & \text{Valid} \\
\hline
\end{array}
\]
The results of the feasibility test can be seen in Table 2. The content aspect of the material gets the largest percentage, this is in accordance with the characteristics of the e-module i.e self-contained that is providing complete learning opportunities with the material packaged in one whole unit [14].

| No  | Rated Aspect                        | Average (%) | Yes | No. |
|-----|-------------------------------------|-------------|-----|-----|
| 1.  | Material substance aspects          | 100         | 0   |     |
| 2.  | Evaluation aspects                  | 96.67       | 3.33|     |
| 3.  | Display and navigation aspects      | 97.65       | 2.35|     |
|     | Average percentage                  | 98.11       | 1.89|     |

4. Conclusion
E-module is created by combining text, images, videos, animations, simulations and questions with direct feedback, systematically and interactively based on the POE learning model which includes sub-concepts of dynamic equilibrium, homogeneous and heterogeneous equilibrium, and factors that influence chemical equilibrium. Validation result produce an overall average calculation of 0.87 while the results of the feasibility test conducted at ten students show a percentage of 98.11%. This shows that this e-module is very feasible to be used as teaching material.

References
[1] Sugiarti R and Farida I 2013 Analisis buku teks kimia SMA pada konsep kesetimbangan kimia ditinjau dari kriteria representasi Pros. Simp. Nasional Inovasi dan Pembelajaran Sains (Bandung: Indonesia) pp 216–219
[2] Barke H-D, Hazari A and Yitbarek S 2009 Misconceptions In Chemistry (Germany: Springer)
[3] Quilez J 2009 From chemical forces to chemical rates: a historical / philosophical foundation for the teaching of chemical equilibrium Sci. Educ. 9 5
[4] Tasker R and Dalton R 2006 Research into practice: visualisation of the molecular world using animations Chem. Educ. Research and Practice. 7 141–59
[5] Chittleborough G and Treagust D F 2007 The modeling ability of non-major chemistry students and their understanding of the sub-microscopic level Chem. Educ. Research and Practice 8 274–92
[6] Wu H and Shah P 2004 Exploring visuospatial thinking in chemistry learning Sci. Educ. 3 465–92
[7] Jones L L and Kelly R M 2015 Visualization: the key to understanding In Sputnik to Smartphones (Washington, DC: American Chemical Society) pp 121-35
[8] Farida I 2009 The importance of development of representational competence in chemical problem solving using interactive multimedia. Proc. of The Third Int. Seminar on Sci. Educ. . (University of Education: Indonesia)
[9] Kozma R and Russell J 2005. Students Becoming Chemists: Developing Representational Competence, ed J K.Gilbert (Dordrecht: Springer) pp 121–45
[10] Karpudewan M, Treagust D F, Mocerino M, Won M and Chandrasegaran A 2015 Investigating high school students’ understanding of chemical equilibrium concepts Int. J. of Environmental & Sci. Educ. 10 pp 845–63
[11] Muntholib, Yunisari Y D and Afandy D 2016 Pengembangan bahan ajar kesetimbangan kimia untuk siswa kelas XI SMA/MA menggunakan pendekatan saintifik 5M Pros. Seminar Nasional Kimia dan Pembelajarannya (Universitas Negeri Malang: Indonesia) pp 330–335
[12] Syamsurizal, Haryanto and Chairani N 2015 Pros. SEMIRATA 2015 bidang MIPA BKS-PTN Barat (Universitas Tanjungpura: Indonesia) pp 655-61
[13] Irwansyah F S, Lubab I, Farida I and Ramdhani M A 2017 Designing Interactive Electronic Module in Chemistry Lessons J. Phys: Conf. Ser. (Bandung: Indonesia) 895 012009

[14] Depdiknas 2008 Penulisan Modul Jakarta: Direktorat Tenaga Kependidikan

[15] Sudiadnyani P, Sudana D N and Garminah N N 2013 Pengaruh model pembelajaran predict-observe-explain (POE) terhadap pemahaman konsep IPA siswa kelas IV SD kelurahan banyuasri MIMBAR PGSD Undiksha, 1 1–10

[16] Joyce C 2006 Predict, observe, explain (POE). [Online]. Available: https://arbs.nzcer.org.nz/printpdf/7187

[17] Vavra K L, Janjic-watrich V, Loerke K., Phillips L M, Norris S P and Macnab J 2011 Visualization in science education ASEJ 41 22–30

[18] Branch R M and Dousay T A 2015 Survey of instructional design models (V) (Association for Educational Communications and Technology: Bloomington, Indiana USA)

[19] Sugiyono 2017 Metode penelitian pendidikan (pendekatan kuantitatif, kualitatif dan R & D (Alfabeta: Bandung)

[20] Arikunto 2013 Prosedur penelitian suatu pendekatan praktik (Rineka Cipta: Jakarta)

[21] Devetak I 2013 The criteria for evaluating the quality of the science textbooks (University of Ljubljana, Kardeljeva: Slovenia)

[22] Nuraini N, Karyanto P and Sudarisman S 2014 Pengembangan modul berbasis POE predict, observe, and explain) disertai roundhouse diagram untuk memberdayakan keterampilan proses sains dan kemampuan menjelaskan siswa kelas X SMA negeri 5 surakarta BIOEDUKASI 7 39

[23] Rahayu S, Widodo A T and Sudarmin 2013 Pengembangan perangkat pembelajaran model POE berbantuan media “i am a scientist.” Innov. J. Curric. Educ. Technol. 2 128–133