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Development of Chemical Equilibrium E-Module Guided by 5E Instructional Model with Interactive Virtual Laboratory

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Abstract: E-module is a form of electronic teaching material that can be used independently, with each learning activity connected by a link. 5E Instructional Model is a learning model that was developed based on constructivism learning, where students construct their own knowledge and are actively involved in every stage of the learning process. This study aims to develop a chemical equilibrium e-module based on an integrated 5E instructional virtual laboratory, as well as to determine the level of validity and practicality. The development of the e-module is carried out through the Plomp model stage which consists of 3 stages, namely preliminary research, prototyping phase, and assessment phase. The assessment instruments used are observation sheets and questionnaires. The results showed that the e-module developed was valid and practical so that it could be used in the learning process.

Keywords: e-modul, 5E instructional model, chemical equilibrium

Abstrak: *E-modul adalah suatu bentuk bahan ajar elektronik yang dapat digunakan secara mandiri, dengan setiap kegiatan pembelajaran dihubungkan dengan oleh suatu link. 5E Instructional Model merupakan suatu model pembelajaran yang dikembangkan berdasarkan pembelajaran konstrutivisme, dimana peserta didik mengkonstruk pengetahuannya sendiri dan terlibat aktif dalam setiap tahap proses pembelajaran. Penelitian ini bertujuan untuk mengembangkan e-modul kesetimbangan kimia berbasis 5E instructional terintegrasi virtual laboratorium, serta menentukan tingkat validitas dan praktikalitasnya. Pengembangan e-modul dilakukan melalui tahapan model Plomp yang terdiri 3 tahap yaitu preliminary research, prototyping phase, dan assesment phase. Instrumen penilaian yang digunakan yaitu lembar observasi dan angket. Hasil penelitian menunjukkan bahwa e-modul yang dikembangkan telah valid dan praktis sehingga dapat digunakan dalam proses pembelajaran.*

Kata kunci: *e-modul, model pembelajaran 5E, kesetimbangan kimia.*

▪ INTRODUCTION

Chemical equilibrium material is material that students learn at the end of the odd semester of second class in senior high school. Chemical equilibrium is a prerequisite material that students must master before studying acid-base material, ionic balance in salt solutions, and buffer solutions. Therefore, it is necessary to understand the concept of chemical equilibrium so that it is easier for students to master the following material. However, students still experience misconceptions about chemical equilibrium material because the material is abstract so it is difficult to understand the concept of the material (Andriani et al., 2021; Karpudewan et al., 2015; Satriana et al., 2018).

Misconceptions relate to how students build their mental models. In general, students express their knowledge at the macroscopic level better than at the submicroscopic and symbolic levels. Based on research conducted by Gayatri, (2018) dan Rusli (2018), the profile of the mental model of students in the dynamic equilibrium sub-

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material there are 63% of students do not understand, the concept of the equilibrium constant there are 86 % of students still experiencing misconceptions, for the material of shifting the direction of equilibrium there are 53% of students have misconceptions. The mental model profile shows that students' understanding of the chemical equilibrium material is still low.

2013 revised 2018 curriculum guides students to be competent in mastering the 21st century. 21st-century learning integrates knowledge, attitudes, and mastery of technology (Kemendikbud, 2017a). Skills commonly used in 21st-century learning are known as 4C (communication, creativity, collaboration, and critical thinking) (Soule & Warrick, 2015). Critical thinking or what is known as critical thinking skills if done actively can improve understanding of concepts by way of evaluation through observation, experience, reasoning, and communication. Providing learning materials related to everyday life can also improve students' critical thinking skills (Snyder & Snyder, 2008).

In addition to 21st-century learning, students are also required to be able to follow the era of the industrial revolution 4.0. Industrial revolution 4.0 is an era of integrated technology discovery using knowledge. Learning in this era can be done anytime and anywhere (Utomo, 2019). The 2013 curriculum, 21st-century learning, and the industrial revolution 4.0 which is the era of digitalization in various fields including education can be an opportunity to develop an alternative learning media that is valid, practical, and effective to use.

One of the alternative learning media that can be used in accordance with the demands of the 2013 Curriculum and the Industrial Revolution 4.0 is the electronic module or e-module. E-module is a form of electronic teaching material that can be used independently, with each learning activity connected by a link and equipped with learning videos, animations, pictures, and audio to help students learn (Kemendikbud, 2017b).

One of the learning models that can improve students' critical thinking skills is 5E instructional. Learning using the 5E instructional model begins with the engagement stage, where the teacher plays a role in generating student interest in learning and motivating students before starting the learning material. Furthermore, in the exploration stage, the teacher helps students to explore the concept of a lesson and then provides opportunities for students to explain in their own language related to the learning material (explanation). Then in the elaboration stage, students apply the knowledge they have acquired and if there are still misconceptions, students can discuss them with the teacher or peers. Finally, in the evaluation stage, the teacher measures the extent to which students understand the learning material (Bybee, 2014). That way learning becomes student-centered so that learning becomes meaningful (Bahtaji, 2021; Kadıoğlu & Çetin, 2021; Salar & Turgut, 2021).

Several research results regarding teaching materials in the form of e-modules and 5E instructional models are very effective in the learning process. E-modules in chemistry subjects have a fairly high level of validity, practicality, and effectiveness so that they can be used in the learning process both online and offline (Adriani et al., 2021; Fibonacci et al., 2021; Kuit & Osman, 2021; Linda et al., 2018; Lisa Rosanna et al., 2021). Child-centered pedagogy of learning with the 5E instructional model is suitable for greater interactivity between teacher and child, environmental and social (Desouza, 2017; Siwawetkul & Koraneekij, 2020; Ulukaya Oteles, 2020). The implementation of the e-module on lipid metabolism material shows an increase in students' critical thinking skills (Seruni et al., 2020). The development of e-modules on fluid materials shows valid and practical results in the very good category (Sari et al., 2019). In addition, in mathematics

subjects, the use of e-modules also gets results that are very suitable for use by students and can improve creative thinking skills (Kusumaningtyas & Supaman, 2020; Perdana et al., 2017). Based on the explanation of the background, the research question that this research wants to answer is how is the validity and practicality of e-modules on chemical equilibrium materials.

▪ METHOD

The type of research conducted is educational design research or known as EDR. The development model used in this research is the Plomp development model. This model was developed by Tjeerd Plomp in 3 stages, namely: (1) preliminary research; (2) prototyping phase, and (3) assessment phase. The subjects of this research trial were lecturers of chemistry and educational technology at Padang State University and students in class XI of SMAN 5 Padangsidimpuan in the 2021/2022 academic year.

The first step in this research is preliminary research. At this stage, needs analysis, context analysis, literature study, and conceptual framework development are carried out. Needs analysis was carried out through the distribution of observation questionnaires for teachers and students at SMAN 1 Padangsidimpuan, SMAN 5 Padangsidimpuan, and SMAS Nurul Ilmi Padangsidimpuan. In the context analysis stage, an analysis of the curriculum and syllabus is carried out. In the literature study stage, the search for sources and references related to research activities is carried out. At the stage of developing the conceptual framework, identification, detailing, and preparation of the main concepts in the chemical equilibrium material are carried out.

The second stage is the formation of a prototype (prototyping stage). At this stage, an e-module design based on the 5E Instructional model on chemical equilibrium material for class XI SMA/MA students is prepared based on the results of the analysis at the preliminary research stage accompanied by Tessmer's formative evaluation.

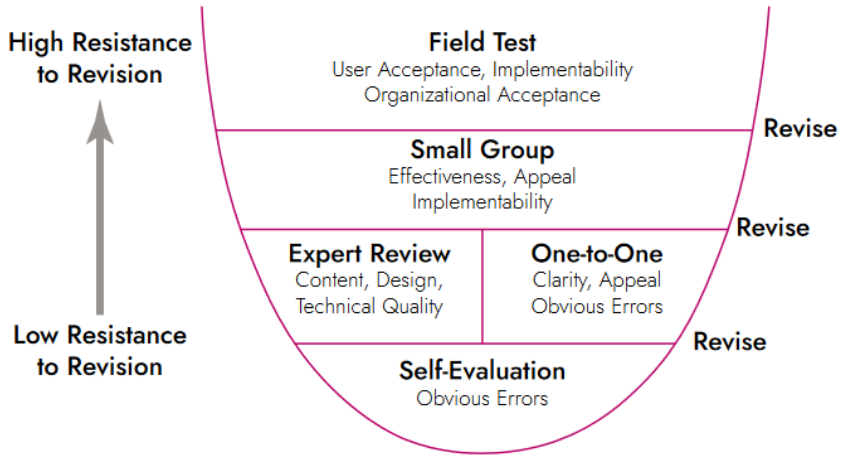

Figure 1. Tessmer's Formative Evaluation Stages (Plomp & Nieveen, 2007)

The instrument used in this study is a validity instrument and a practical instrument in the form of a questionnaire. Aspects assessed on the validity of the material are content, language, serving, and graphics. As for the validity of the media assessed, namely components, content, interfaces, interactivity, and technology. The score obtained from the material validation sheet and media validation will be calculated using Aiken's V formula. The e-module is said to be valid if the validity value > 0.8 (Retnawati, 2016).

Aspects assessed to test practicality are ease of use, study time efficiency, and benefits. The score obtained from the practicality sheet will be calculated using the Kunandar formula (Kunandar, 2015). E-modules are said to be practical if they get a practicality value > 80% (Riduwan, 2008).

▪ RESULT AND DISCUSSION

1. Preliminary Research

A needs analysis was carried out through interviews with chemistry teachers and filling out questionnaires by students. The purpose of interviews with teachers and students is to find out the teaching materials used by teachers, and the difficulties faced by students, as well as the learning models used by teachers. Based on the results of the interview, it is known that the teaching materials used by the teacher are textbooks, worksheet, modules, learning videos, and powerpoint. Online learning teachers use application assistance in the form of google classroom and WhatsApp, while the learning model is still rarely used by teachers. Based on the results of the questionnaire, it is known that the chemical equilibrium material is a material that is considered difficult by students because the material is too much, abstract, and also uses a lot of calculations. Even though chemical equilibrium is one of the core topics that students need to understand before studying the next chemical material (Aini et al., 2019). Based on the results of the questionnaire distributed to students, 83.8% of students stated that chemical equilibrium material was difficult, 78.1% said the reason for the difficult equilibrium material was because there were too many calculations that were difficult to understand, 28.9% said the material was too much, and the rest said the material was too abstract and the online learning conditions due to the covid-19 pandemic made it difficult to understand the virtual learning material. Therefore, researchers created alternative learning media in the form of e-modules which are expected to help students and teachers in the learning process, especially during the current pandemic.

Context analysis aims to determine the outlines of the material to be taught. The analysis of the chemical equilibrium material is carried out on basic competencies 3.8; 3.9; 4.8; and 4.9. Based on the basic competencies, it is then formulated as an indicator of competency achievement and learning objectives. Literature review from several journals relevant to this study regarding the use of learning models in as many as 5 journals and teaching materials in the form of e-modules in as many as 5 journals. The effect of the 5E instructional model obtained an average effect size of 2.14 with a high influence on learning outcomes and for the use of e-modules an effect size of 3.7 was obtained with a high influence on learning outcomes. So that the use of the 5E instructional model and e-module is good for research because it affects learning outcomes. Based on the concept analysis, it is found that the main concepts must be mastered by students, namely: reversible and irreversible reactions, dynamic equilibrium, equilibrium constants Kc and Kp, Kc and Kp relations, dissociation equilibrium, factors that affect the shift in equilibrium direction, and balance in the industry.

2. Prototyping Phase

The prototype I is the design and realization of the preliminary research. The prototype I was produced in the form of an e-module containing a cover, introduction, table of contents, list of pictures, list of videos, learning instructions, work safety in the laboratory, hazard symbols, laboratory equipment, core competencies, basic

competencies, objectives learning, activity sheets, worksheets, evaluation sheets, answer keys and bibliography.

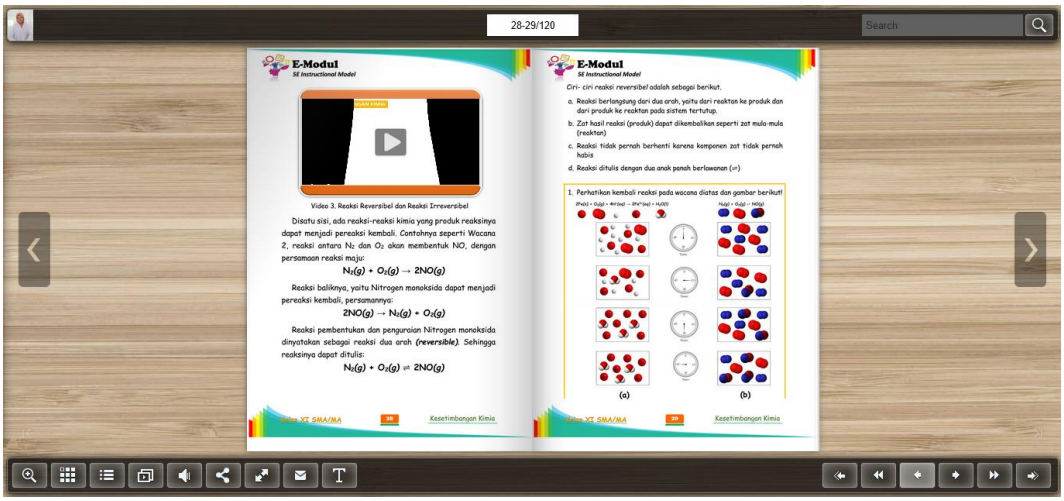

Figure 2. Example display of e-module

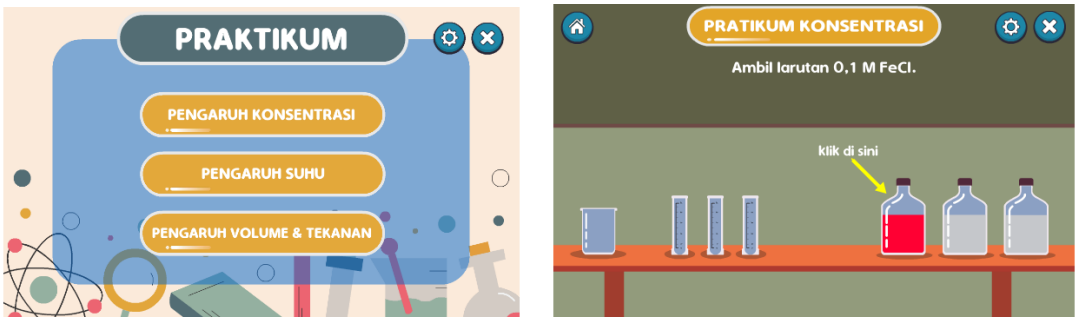

Figure 3. Example of virtual laboratory display

In prototype stage II, a formative evaluation was carried out in the form of a self-evaluation of the prototype I that had been produced. Based on the results of self-evaluation, the prototype I require revisions to several parts of the e-module, namely the addition of instructions for use and a glossary.

Figure 4. Instructions for using e-module

At prototype stage III, a formative evaluation is carried out in the form of a one-to-one evaluation and expert review. Based on the analysis of the results of a one-to-one evaluation of the chemical equilibrium e-module based on the 5E instructional model, it is obtained that the letters used in the e-module are clear and easy to read, the cover and color design of the e-module display is good so that it attracts students' interest in reading it, and the language used is easy to understand. The presentation of material in the e-module is in accordance with the 5E Instructional stages so that it can guide students to find new knowledge and can make students hone their thinking skills.

The prototype II that has been produced is validated by material expert validators and media expert validators. The assessment of the validity of the material shows that the chemical equilibrium e-module has an Aiken's average value of 0.91 with a valid category. The results of the data analysis of the e-module material validation can be seen in Table 3.

Table 1. Material Validation Analysis

Rated Aspect	Aiken's V	Category
Content	0.88	Valid
Language	0.92	Valid
Serving	0.88	Valid
Graphic	0.94	Valid
The average value of V	**0.91**	**Valid**

The average value of Aiken's V obtained shows that the chemical equilibrium e-module based on the 5E instructional model developed is in accordance with the learning objectives to be achieved and the material provided is in accordance with the abilities of students. This is in accordance with the theory that content validity indicates a product developed according to the curriculum and based on a strong theoretical rationale (Rochmad, 2012).

The e-module developed uses good, simple, and clear Indonesian rules so that it is easily understood by e-module users. Kemendikbud (2017) states that a good e-module should use simple, easy-to-understand language and put forward general terms so that it is user-friendly. A learning media fulfills content validity, meaning that all components of the learning media developed are supported by theories that are quite broad and mutually support each other to achieve learning goals (Plomp & Nieveen, 2007). The media validity assessment showed that the chemical equilibrium e-module had an average Aiken's V value of 0.93 with a valid category. The results of the data analysis of the e-module material validation can be seen in Table 4.

Table 2. Media Validation Analysis

Rated Aspect	Aiken's V	Category
Component	0.95	Valid
Content	0.88	Valid
Interface	0.97	Valid
Interactivity	0.96	Valid
Technology	0.92	Valid
The average value of V	**0.93**	**Valid**

The average value of Aiken's V obtained shows that the chemical equilibrium e-module based on the 5E instructional model developed is complete, clear and

systematically arranged. In this case, what is meant by e-module components are introductions, instructions for use, materials, evaluation questions and other supporting multimedia (images, audio and video). The feasibility of e-module content greatly affects the interactions that will occur in the learning process. Bozkurt & Bozkaya (2015) state that the true e-module interaction is not given entirely by the technology used, but is also influenced by content design.

For the formation of prototype IV, a small group test was conducted on 6 students with different ability levels. This stage aims to revise whether there are still deficiencies in the e-module that has been developed before being tested at the field test stage. The results of the data analysis of the e-module material validation can be seen in Table 5.

Table 3. Small Group Test Results

Rated Aspect	Value	Category
Ease of use	0.86	Very Practical
Study time efficiency	0.88	Very Practical
Benefit	0.82	Very Practical
Average value	**0.85**	Very Practical

The average value of Aiken's V is 0.85 with a very practical category, proving that this 5E instructional-based chemical equilibrium e-module makes it easier for students to understand chemical equilibrium material. This is in accordance with one of the characteristics of e-modules, which is user-friendly (Kemendikbud, 2017b). Ease of use is certainly related to the clarity of learning materials, language that is easy to understand and the letters used are clear and easy to read. This is in accordance with the principle of e-module development, namely e-modules are arranged according to the needs and objectives of learning and communicative language (Asmiyunda et al., 2018).

3. Assessment Phase

The practicality of the e-module that has been developed is obtained through (1) the results of the assessment of 30 students on the e-module that has been developed, and (2) the results of the teacher's response to the developed e-module. The results of the e-module practicality data analysis can be seen in Table 6.

Table 4. E-Module Field Test Result

Rated Aspect	Teacher	Students	Category
Ease of use	0.92	0.87	Very Practical
Study time efficiency	0.80	0.85	Very Practical
Benefit	0.88	0.82	Very Practical
Average value	**0.89**	**0.85**	Very Practical

The average value of Aiken's V teachers and students is 0.89 and 0.85 with a very practical category. This shows that the developed e-module has a very practical level of practicality. This shows that the e-module that has been developed can help students become independent in finding concepts from learning materials. Therefore, the 5E instructional-based chemical equilibrium e-module is useful in learning chemical equilibrium. This ease of use relates to the language of the e-module which is clear and easy for students to understand and the material contained in the e-module is clear and simple (Asmiyunda et al., 2018).

▪ CONCLUSION

An e-module chemical equilibrium based on an integrated virtual laboratory 5E instructional model has been produced through Educational Design Research with the plomp development model. The validity results obtained a value of 0.91 with a valid category for material validity and 0.93 with a valid category for media validity. The results of the practicality of teachers and students obtained values of 0.89 and 0.85 with a very practical category. So it can be concluded that the e-module that has been developed is valid and practical to use in the learning process. The drawback of this research is that it is necessary to conduct further effectiveness tests to see its effect on learning outcomes. The implication of this research is that one of the alternative teaching materials can be used by teachers and students in the online or offline learning process.

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