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Development of A Stem E-Module Based on Project Based Learning on Chemical Equilibrium Material

Dinda Natalisa Br Gurusinga*, Eddiyanto, Agustina Ruth Lita Sirait, Dira Khairunisa, Graceana Ambarita, Nabilla Sri Ayuandiva, Zevi J. Sinaga

Dapartement of Chemistry Education, Faculty of Mathematics and Natural Sciences,
University of Medan
Jl. W. Iskandar Psr V Medan Esatate District. Deli Serdang, Indonesia

*Correspondinge-mail: dindagursing123@gmail.com

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Abstract : Development Of A STEM E-Module Based On Project Based Learning On Chemical Equilibrium Material. This research aims to: (1) To determine the validity of the STEM e-module based on Project Based Learning (PjBL) on chemical equilibrium material. (2) To determine students' responses to STEM e-modules based on PjBL on chemical equilibrium material. The research background highlights the challenges of 21st century learning where learning is carried out by utilizing technology and using an independent curriculum where the learning process is student-centered. So the STEM-PjBL e-module is an alternative that students can use in the learning process with flexibility. Science, Technology, Engineering, and Mathematics (STEM) is an alternative learning solution for the 21st century. The development model used is the ADDIE Model which consists of five stages including Analysis, Design, Development, Implementation and Evaluation. The e-module assessment instrument is a validation instrument from material and design experts as well as a student response questionnaire in the form of a Likert scale. The research results show that (1) the validation of the STEM e-module based on PjBL on chemical equilibrium material is "very valid" with an average percentage of 88.30%; (2) students' responses to the application of project-based learning-based STEM e-modules on chemical equilibrium material show that the e-modules developed are categorized as "very practical" with an average percentage of 90.51%.

Keywords: E-Module, STEM, Project, Chemical Equilibrium

Abstrak : Pengembangan E-Modul STEM Berbasis Project Based Learning Pada Materi Kesetimbangan Kimia. Penelitian ini bertujuan untuk: (1) Untuk mengetahui validitas e- modul STEM berbasis PjBL pada materi kesetimbangan kimia. (2) Untuk mengetahui respon peserta didik terhadap e-modul STEM berbasis PjBL pada materi kesetimbangan kimia. Latar belakang penelitian menyoroti tantangan pembelajaran abad 21 dimana pembelajaran dilaksanakan dengan memanfaatkan teknologi dan penggunaan kurikulum merdeka dimana proses pembelajarannya berpusat pada peserta didik. Sehingga e-modul STEM-PjBL merupakan salah satu alternatif yang dapat digunakan siswa dalam proses pembelajaran secara fleksibilitas. Sains, Technology, Engineering, and Mathematics (STEM) adalah solusi pembelajaran alternatif untuk abad ke-21. Model pengembangan yang digunakan adalah Model ADDIE yang terdiri dari lima tahap

diantaranya adalah Analisis (Analyze), Desain (Design), Pengembangan (Development), Pelaksanaan (Implementation) dan Evaluasi (Evaluation). Instrumen penilaian e-modul berupa instrumen validasi dari ahli materi dan desain serta angket respon peserta didik dalam bentuk skala Likert. Hasil penelitian menunjukkan bahwa (1) validasi e-modul STEM berbasis PjBL pada materi kesetimbangan kimia "sangat valid" dengan persentase rata-rata sebesar 88,30%; (2) respon peserta didik terhadap penerapan e-modul STEM berbasis PjBL pada materi kesetimbangan kimia menunjukkan bahwa e-modul yang dikembangkan terkategori "sangat praktis" dengan hasil rata-rata persentase sebesar 90,51%.

Kata kunci: *E-Modul, STEM, Project, Kesetimbangan Kimia*

▪ INTRODUCTION

The 21st century national education system faces complex challenges to prepare human resources that are qualified, skilled and able to answer global educational challenges (Irmita, 2018). Education plays an important role in shaping the character of the nation's next generation. In education, the learning process in the classroom is very dependent on learning resources, including teachers, books, modules and the teacher's skills in delivering learning. The learning process involving Science, Technology, Engineering, and Mathematics (STEM) is an alternative learning solution for the 21st century. According to Afriana et al., (2016) STEM is a scientific discipline closely related to each other. Approach STEM in learning is expected to produce good learning meaningful for students through integration knowledge, concepts, and skills systematically. The STEM approach can be innovated with chemistry so that this approach can be carried out on chemical materials that are closely related to life everyday with interrelationships 4 inside aspect STEM (Raisha at al., 2021).

Technological advances have caused the learning process to change, namely from paper to online, from physical facilities to network facilities, and from the classroom to anywhere and anytime so that the application of educational media has an important role in learning. Educational media has also experienced changes, namely through the use of soft copy media in the form of electronic modules (Siregar dan Harahap, 2022).

The use of electronic modules (e-modules) can help teachers in the learning process. E-modules can help students study subject matter independently because they use electronic media. This causes the teacher in learning only to act as a facilitator (Laraphaty., 2021). With this interactive electronic module, the learning process will involve audio-visual displays, sound, movies and others and the use of the program is easy to understand so it can be used as a good learning medium (Linda & Putra, 2021).

Based on research conducted by Karnia dkk., (2022) on the development of STEM (Science, Technology, Engineering, and Mathematics) based e-modules on acid base material, it can attract students' interest and motivation and is able to train students' scientific attitudes so that they are actively involved. in learning. And according to (Angraini et al., 2022) e-modules based on the STEM approach are feasible both theoretically and practically for use in learning chemistry material in Natural Sciences.

Research by Tripripa.dkk., (2020) states that there are shortcomings in the development of STEM-based e-modules, namely that the development of ce-modules only emphasizes student independence in learning to discover concepts, so interactive tasks must be added to increase student understanding. In addition, future researchers are

advised to develop e-modules based on an integrated STEM approach in other materials. This aims to make the development of STEM e-modules better and improve students' analytical skills regarding subject matter.

Project based learning is a learning model that uses projects or activities in the learning process. Through the PjBL learning form, students can explore, assess, interpret, synthesize and obtain information. In PjBL students are given projects that are complex and quite difficult but complete and realistic and can then be given sufficient assistance so that students can complete the task (Berhitu et al., 2020). This model is also designed to guide students through collaborative projects that integrate various learning resources (materials). This model gives students the opportunity to explore learning content (materials) using various ways that are meaningful for students and collaborate in conducting experiments. The PjBL learning model is a student-centered learning model. Project based learning can also increase 58.33% in cognitive aspects, 66.7% in affective aspects and 91.65% in psychomotor aspects as proven through research (Made et al., 2022) after using the PjBL method.

Research conducted by Anita, et al (2019) regarding implementation of the STEM-based PjBL model to improve mastery of concepts and abilities analytical thinking student. The results of this research are concluded that the implementation of the STEM-based PjBL model can increase mastery students' concepts and analytical thinking abilities. Roopnarine and Johnson in (Arisanti, 2017) stated that the aim of the PjBL model is to provide a variety of experiences learn to form roles in the process of responding to each other's ideas, organize the efforts and different contributions of group members, finish dispute, how problem solve and resolve assignments so as to improve student learning by creating a good environment.

Chemistry subjects include difficult material because chemistry subjects contain complex concepts, there is a lot of memorization and calculations using formulas so that most students find it difficult to understand the use of quite a lot of formulas during chemistry lessons and apply chemistry material in everyday life. Chemical equilibrium material is one of the materials that is quite difficult, this happens because chemical equilibrium material explains changes in equilibrium states in a reaction which are at the sub-microscopic (molecular) level so that it is difficult to observe with the naked eye (Adawiyah et al., 2021).

Based on the results of interviews with chemistry teachers at SMA Santo Thomas 4 Binjai, it shows that chemical equilibrium material is also material that is difficult to learn because it focuses on mastering symbols, memorizing formulas and solving problems mathematically. This makes it difficult for students to fully understand chemical equilibrium material and relate the material studied to everyday life. Implementation STEM is still minimally implemented in schools due to the limited knowledge of educators regarding the steps of the approach STEM to be applied in the learning process. And based on the results of observations by researchers with students at SMA Santo Thomas 4 Binjai, it shows that the difficulty of understanding chemical material is influenced by the condition of the teaching materials. The teaching materials used at this school are textbooks (package books).

▪ METHOD

This research was conducted at SMA Santo Thomas 4 Binjai Jalan Ikan Tenggiri No.21, Highlands, Kec. East Binjai., Binjai City, North Sumatra Province. The research

was carried out from August 2024 to November 2024. The sampling technique used in this research was Purposive Sampling. The sample used in this research was class XII A, totaling 39 people.

This research uses a development model or in English it is called Research and Development (R&D). Development research is a research method used to produce certain products, and to test the effectiveness of these products (Hidayat et al., 2021). This development research uses the ADDIE model. The ADDIE model consists of five stages including Analysis, Design, Development, Implementation and Evaluation (Anggraeni & Rahmawan, 2024).

Analysis Stage (Analyze)

The first stage in the ADDIE development model is analysis. Researchers conducted a needs analysis through observations during the learning process of chemical equilibrium subjects. The analysis carried out was curriculum analysis, syllabus analysis, and chemistry book analysis which was used to find out the curriculum and syllabus and chemistry books used by high schools. So that data is obtained as basic material for drafting PjBL-based STEM e-modules.

Design Stage (Design)

After the analysis stage was carried out, the next step was for the researcher to carry out the planning stage (Design) regarding the design of the e-module structure which would be developed into a PjBL-based STEM e-module by paying attention to the strengths and weaknesses of the books being analyzed (Hidayat et al., 2021).

At the stage of creating the e-module design, researchers will use the Canva website and flipbook as assistants in the editing process for creating the e-module.

Development Stage (Development)

The third stage in the ADDIE development model is development. At the development stage, PJBL-based STEM e-modules were created. After the e-module is completed in the form of a finished product, it is reviewed by the supervisor before being validated by an expert. The validation process is carried out with the aim of determining the level of appropriateness of the media as well as getting advice and input from experts to improve the quality of the learning media product before distributing it to students.

Implementation Stage

The fourth stage in the ADDIE development model is implementation. After the PJBL-based STEM e-module has been declared suitable for use in research by experts, the stage of distributing the e-module to students is carried out. The aim is to find out students' responses after using e-modules in learning.

Evaluation Stage (Evaluation)

At this stage, evaluation is carried out as development progresses, so that deficiencies during the development process can be identified and resolved. At this stage, every suggestion and input obtained in the STEM-PjBL e-module development process from the validation stage to student respondents will be improved to produce a good e-module that meets the required needs.

The research instruments used were interview sheets, needs analysis questionnaires, teaching material analysis sheets, e-module validation sheets (the points on the e-module

validation sheets come from BSNP teaching material evaluations), student and chemistry teacher response questionnaires. Analysis of e-module validation data is qualitative in the form of suggestions or comments, while the data used in validation is quantitative with reference to five assessment criteria (Sofwatillah et al., 2024). Validation by the validator team uses a percentage score derived from a Likert scale. The assessment criteria are presented in Table 1**.**

Tabel 1. Likert Scale

Nilai Skala	Penilaian
4	Very worth using
3	Quite worthy of use
2	Not suitable for use
1	Not really worth using

(**Sumber:** Rosalina, 2017)

Then the data that has been obtained is converted into qualitative values according to the criteria above. Validation score percentage formula:

$$P = \frac{F}{N} \; x \; 100\% \text{.....Equation (1)}$$

Information :

P: Percentage

F : Score obtained

N : Maximum score

So it can be categorized as validation criteria which can be seen in Table 2**.**

Tabel 2. Validity Criteria

Rentang Persentase (%)	Kriteria
80% – 100%	Very Valid
60% – 80%	Valid
40% – 60%	Fairly Valid
20% – 40%	Less Valid
0% – 20%	Invalid

(**Sumber:** Karnia dkk., 2022)

The response questionnaire for students contains 14 statement items indicating responses to PjBL based STEM e-modules. The questionnaire was created using a Likert scale, the assessment criteria can be seen in Table 3**:**

Tabel 3. Likert Scale

Nilai Skala	Penilaian
4	Strongly agree
3	Agree
2	Don't agree

Nilai Skala	Penilaian
1	Strongly disagree

(**Sumber:** Yuliarmi & Marhaeni, 2019)

To analyze response data, this research uses percentages. The percentage of student and teacher response scores uses the formula in Equation 1. After the percentage is obtained, it is then matched with the practicality assessment guideline criteria (Akbar, 2013) which is presented in Table 4**.**

Tabel 4. Practicality Criteria

Rentang Persentase (%)	Kriteria
80% – 100	Very Practical
60% – 80	Practical
40% – 60	Quite Practical
20% – 40	Less Practical
0% – 20	Impractical

(**Sumber :** Akbar, 2013)

▪ RESULT AND DISCUSSION

The research was carried out in August 2024 - November 2024 at SMA Santo Thomas 4 Binjai. The development of a STEM e-module based on PjBL on chemical material equilibrium was carried out at the data collection stage by distributing questionnaires to class XII IPA A students and interviews with class XII chemistry teachers to analyze the needs for the teaching materials used. The data obtained will later be used as a guide in preparing the e-module design that will be developed. The following is a discussion of the research that has been carried out by researchers:

Analysis Stage

At this stage the researcher carried out a needs analysis in the form of distributing questionnaires to students and interviewing teachers, as well as analyzing teaching materials. Questionnaires were distributed to 39 students of class XII IPA A SMA Santo Thomas 4 Binjai to determine the need for teaching materials. Apart from that, a needs analysis was also carried out by interviewing chemistry teachers at Santo Thomas 4 Binjai High School. From the results of the analysis that has been carried out, there is a problem with students' needs for new teaching materials during the chemistry learning process. So, from these problems the researcher concluded that students and teachers at SMA Santo Thomas 4 Binjai needed a solution that could overcome the problems at school. Next, an analysis of teaching materials in high school chemistry books was carried out. Here the researcher analyzed 3 books, where the book used in class Analysis of teaching materials is carried out to determine the completeness of the teaching materials used in learning. The three books analyzed do not contain STEM and PjBL. This analysis of teaching materials is carried out to identify the advantages and disadvantages of teaching materials, which are then used as a basis for the development of e-modules (Reza & Syamsurizal, 2021).

Design Stage

After analyzing needs and analyzing teaching materials, the next stage is preparing the initial draft of the e-module. The e-module draft is the initial design or concept used to develop the e-module. Things that need to be considered in preparing e-modules are the selection of the e-module format that will be used. The e-module developed was designed using Microsoft Word and the cover was designed using the Canva application. Then combined into Microsoft Word, then the module is converted to PDF and then converted into an e-module using Hyzine Flipbook.

Development Stage

At this stage the creation of the e-module begins. After the preparatory phase module is complete, the module will be converted into PDF format then converted into a flipbook using Hyzine Flipbook and distributed in the form of a website link. Hyzine Flipbook is an application that is capable of converting PDFs into digital turning pages so that interactive learning content can be created with several supporting features (Setiyaningsih et al., 2024). This application is easy to operate on laptops and mobile devices (Febrianti, 2021). The following is an overview of the e-module display that has been developed:

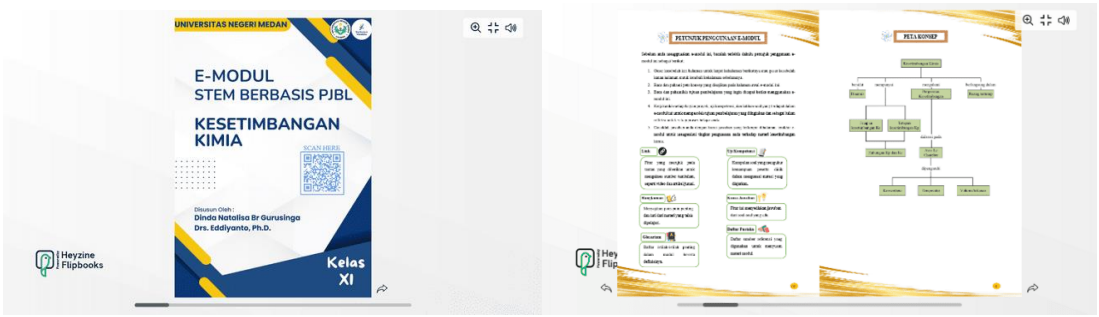

Figure 1. Cover and Instructions for Using the E-Module

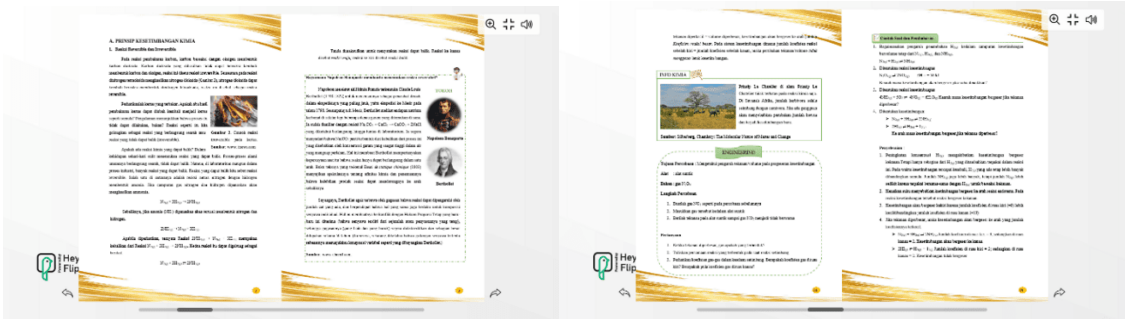

Figure 2. STEM content and pages

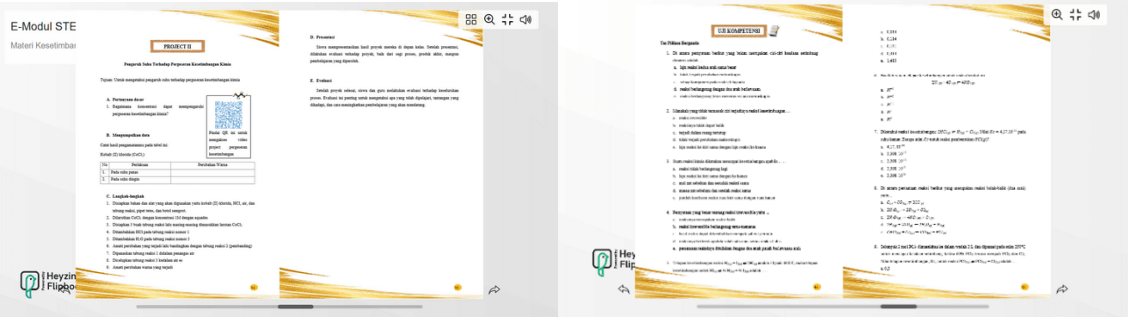

Figure 3. Project and Competency Test

After the e-module is developed, it continues with the e-module validation process by the validator. The material for the expert validity test was given to three chemistry lecturers from Unimed and one chemistry teacher at Santo Thomas 4 Binjai High School. Calculations of e-module validation results are listed in Table 1**.**

Table 1. E-Module Media Validation Results

Assessment Aspects	Persentase Rata-Rata (%)				Average	Validity Criteria
	V1	V2	V3	V4		
Content Eligibility	97,91	79,16	89,58	81,25	86,98	Very Valid
Feasibility of Presentation	95	85	95	82,5	89,38	Very Valid
Language Eligibility	97,5	72,5	87,5	90	86,88	Very Valid
Graphics	94,64	85,71	95,54	83,93	89,96	Very Valid
Average	**96,26**	**80,59**	**91,91**	**84,42**	**88,30**	**Very Valid**
Tafsiran Persentase (%)						

The media expert validity test results obtained an average percentage of 88.30% and were included in the "Very Valid" category. During the validation process, researchers obtained assessments and suggestions from validators used in the e-module revision stage. The revision aims to get a better e-module. Suggestions and input obtained from the validator are to create an answer key, pay attention to writing errors, complete the answer key, pay attention to the spacing of each sentence, pay attention to writing the reaction coefficient, complete the glossary, and tidy up the answer choices a, b, c, d from the competency test questions. from the shortest sentence answer to the longest sentence or from the lowest number value to the highest number value.

E-Modules that have been declared valid are suitable for use in learning (Sakdiah et al., 2020). Based on the percentage of validation results obtained, it can be concluded that the e-module developed is very valid and can be used in the learning process so that the implementation stage can be carried out at SMA Santo Thomas 4 Binjai.

Implementation Stage

This stage was carried out through a limited trial using an e-module that had been developed for use and distribution of response questionnaires to 39 class XII IPA A students at SMA Santo Thomas 4 Binjai. The response questionnaire aims to determine the level of practicality of the e-module. Based on research by Rahayu, et al. (2019), teaching materials are easy to use if student responses get practical results. After using the e-module in class, students were asked to fill out a questionnaire according to their respective opinions based on the experiences they had during the learning activities.

Table 2. Results of Student Responses

Name	Total Score	Maximum Score	Percentage	Category
S1	46	56	82,14	Very Practical
S2	54	56	96,42	Very Practical
S3	48	56	85,71	Very Practical
S4	54	56	96,42	Very Practical
S5	49	56	87,5	Very Practical
S6	54	56	96,42	Very Practical
S7	47	56	83,92	Very Practical
S8	54	56	96,42	Very Practical
S9	42	56	75	Practical
S10	54	56	96,42	Very Practical
S11	46	56	82,14	Very Practical
S12	54	56	96,42	Very Practical
S13	53	56	94,64	Very Practical
S14	54	56	96,42	Very Practical
S15	49	56	87,5	Very Practical
S16	52	56	92,85	Very Practical
S17	42	56	75	Practical
S18	54	56	96,42	Very Practical
S19	47	56	83,92	Very Practical
S20	53	56	94,64	Very Practical
S21	46	56	82,14	Very Practical
S22	43	56	76,78	Practical
S23	54	56	96,42	Very Practical
S24	49	56	87,5	Very Practical
S25	54	56	96,42	Very Practical
S26	49	56	87,5	Very Practical
S27	54	56	96,42	Very Practical
S28	51	56	91,07	Very Practical
S29	54	56	95,42	Very Practical
S30	46	56	82,14	Very Practical
S31	54	56	96,42	Very Practical
S32	47	56	83,92	Very Practical
S33	53	56	94,64	Very Practical
S34	54	56	96,42	Very Practical

Name	Total Score	Maximum Score	Percentage	Category
S35	54	56	96,42	Very Practical
S36	53	56	94,64	Very Practical
S37	51	56	91,07	Very Practical
S38	53	56	94,64	Very Practical
S39	52	56	92,85	Very Practical
Average (%)			**90,51**	

(a) (b)

Fig 2. (a) Use of the STEM-PjBL e-module on chemical equilibrium material for students in the classroom. (b) Distribution of student response questionnaires to the STEM-PjBL e-module regarding chemical equilibrium

The results obtained regarding student responses to the e-module developed obtained an average percentage of 90.51% and were included in the "Very Practical" category. So, it can be concluded that based on the results of the response questionnaire, the e-module developed is classified as "Very Practical" when used in learning, this happens because of the advantages possessed by the e-module developed.

This is in accordance with previous research stated that STEM E-Modules integrated with PjBL can increase student creativity and learning outcomes, so that student responses to the use of e-modules also get good results (Erin et al., 2020).

Evaluation Stage

In making this e-module, researchers experienced obstacles, including (a) choosing a design which took quite a long time because they took into consideration several things so that the e-module being developed could be used well; (b) lack of knowledge about using software to help turn this e-module into a flipbook. This e-Module is an interactive teaching material that can be used in the chemistry learning process. This is because the e-module developed has the following advantages: (a) the e-module can be used on smartphones, laptops and computers; (b) e-modules can be accessed anytime and anywhere; (c) distributing the e-module link is easy, via WhatsApp, Telegram and email; (d) integrated with STEM (Science, Technology, Engineering, and Mathematics) which can broaden students' knowledge of the relationship between chemical equilibria in real life; (e) contains projects; (f) has many other features that can increase students' knowledge. This is in accordance with research conducted by Andi et al., (2015) that the use of e-modules can facilitate the learning process that occurs in the classroom. In the development of this e-module there is a deficiency, namely in access to the e-module must use an internet connection.

▪ CONCLUSION

Based on the results of the research and discussion discussed previously, it can be concluded that the validation of STEM e-modules based on PjBL on chemical equilibrium material is in the "very valid" category with an average percentage of 88.30%. Student responses to the application of e- The STEM module based on PjBL on chemical equilibrium material shows that the e-module developed is "very practical" so it is easy to use in the learning process with an average response percentage of 90.51%.

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